Mind and soil

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Knowledge Aspects of Sustainable Agriculture

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To the engine and source of sustainability in my life

My (little) sister,

Tamara

CONTENTS

1 INTRODUCTION

1.1 Motivation

“Sustainable development has become the catchword for international aid agencies, the jargon of development planners, the theme of conferences and learned papers, and the slogan of developmental and environmental activists”

This statement from Lele (1991) exemplifies what several authors have discussed thoroughly, namely the complexity, and confusion associated with the concept of sustainability (Faber, 2005/2006; Jorna, 2006; Schoot Uiterkamp and Vlek, 2007; Mc Elroy, 2008). Although there is a lack of consistency in its definition (Eden 1994; Jorna 2006) outlining each of the facets of sustainable development that have been discussed in the literature, most of them boil down to three basic concepts: the natural environment, economic profits, and the welfare of the society. The goal of achieving a sustainable planet -one that will provide the basic needs of its present inhabitants while perpetuating the resources that will enable future generations to proliferate- has gained increasing acceptance in several areas. One of the areas that is strongly linked to the sustainability debate is Agriculture. Bell and Morse (2008) argue that problems related to farming practices (such as the careless use of pesticides) have had a major influence in shaping the sustainability concept.

Agriculture involves the transformation of the environment to meet some of the human basic needs, such as food, feed, nutrition, raw materials, clothing and energy. It groups all the activities and the full set of skills and knowledge that men perform on nature to cultivate the land and producing goods through farming. Agriculture has its beginnings in the Neolithic period, when different cultures changed the basis of their nomadic style of hunting, fishing and gathering to a settled lifestyle where the growing and harvesting of crops were developed. The ancient civilizations of Egypt, Mesopotamia, ancient China, and pre-Columbian cultures of Central America are just some examples of this change in life style (Gupta, 2004). Agriculture has evolved over time, not only with cultivated species, but also with the methods and tools used. Altieri (1995) explains how during the 19th and the early 20th centuries, crop yields in agricultural systems depended on internal resources, recycling of organic matter and rainfall patterns. Agricultural yields were modest, but stable. Production was safeguarded by growing more than one crop in space and time in a field as insurance against pest outbreaks or severe weather. Most of the labor was done by the family with occasional hired workers and no specialized services were purchased from off-farm sources. Around 1840, Justus von Liebig debunked the humus theory and made a scientific case for plant requirements for mineral elements from the soil, carbon from CO_2 in the air, and H and O_2 from water (Gillispie, 1990).

Liebig developed the first mineral fertilizers applied to replenish nutrients removed from soils by crops. Liebig's "Law of the Minimum" states that yield is proportional to the amount of the most limiting nutrient, whichever nutrient it may be (van der Ploeg et al., 1999). From this, it may be inferred that if the deficient nutrient is supplied, yields may be improved to the point that some other nutrient is needed in greater quantity than the soil can provide, and the Law of the Minimum would apply in turn to that nutrient. By 1900, nitrogen was being extracted from nitrate mines in Chile (fossil nitrogen) and collected as guano from sea bird excrement (Erisman et al.,2008). The fuel for the transformation was made available by Haber's discovery of ammonia synthesis from its elements, in 1909. What Haber patented was the process of obtaining ammonia by combining hydrogen and nitrogen a high temperature and pressure in the presence of a catalyst like iron oxide (Galloway and Cowling, 2002). The rapid commercialization of this invention, led by Bosch, made large-scale production of ammonia possible by 1913 (Smil, 2001). After the Haber-Bosch was developed, human population started growing rapidly. Although there are several reasons for this, availability of food was an important factor (Galloway and Cowling, 2002).

In order to increase crop yield selecting the best breeds through experimentation is what people have been up to since the beginning of agriculture. In the early 1960s, increasing yields was based on high input systems sustained by several new seed varieties, pesticides and fertilizers, a so-called "Green Revolution." The term "Green Revolution" was coined in the 1960s to highlight a particularly striking breakthrough. In test plots in northwest Mexico, improved varieties of wheat dramatically increased yields. Because of its success in producing more agricultural products there, Green Revolution technologies spread worldwide in the 1950s and 1960s. By the 1970s, the term "revolution" was coined for the new seeds-accompanied by chemical fertilizers, pesticides, and, for the most part, irrigation had replaced the traditional farming practices (Szirmai, 2005). At the European level, agricultural subsidies, directed mainly towards the agri-food industry, obliterate the small local producer. It is estimated that major producers are the main recipients of this aid, while family holdings, supporting rural areas in Europe and farmers in the south of Europe, have virtually no support and suffer from the unfair competition of these highly subsidized products (Holt-Giménez, 2008).

Evidence is now mounting that the productivity that the Green Revolution brought to agricultural systems cannot be sustained. Productivity is being undermined by pollution, salination, soil degradation, and pest and weed build-up (World Bank, 2007). The green revolution has been criticized for bringing large-scale monoculture and input-intensive farming techniques. These farming techniques reap large profits for agribusiness and agrochemical corporations and have been criticized for widening social inequality in the countries owing to uneven food distribution (IAASTD, 2008). For example, Shiva (1991) blames the Green Revolution for the destruction of Indian crop diversity, drought vulnerability, dependence on agrochemicals that poison soils and waterways and for generating "pseudo surpluses" reflecting boosts in wheat and rice production while concealing declines in the production of pulses, oilseeds, and maize. The Green Revolution has been shown to have success in increasing yields but it has imposed an environmental and large human costs. The reasons for these failures may be attributed to the lack of the human dimension in the development of agriculture, and a strong focus on yield maximization at almost any cost, the dominance of disciplinary and reductionist science and its consequences and the weakening of linkages between research, education, extension and practice (Kelly, 2009). Little attention has been paid to a more integrated natural resource management with food and nutritional security (IAASTD, 2009). Agriculture is not just about putting seeds in the ground and then harvesting the crop. Science and technology systems that enhance sustainability whilst maintaining productivity are needed (Williams and Saunders, 2005). To do this, an improved understanding of the context in which farming occurs is needed. Agriculture is being faced by the increasingly social and environmental pressure that will in large part determine the future capacity of agriculture to provide goods in a manner that is sustainable in the XXI century (Bruinsma, 2009). Briefly, global agricultural production must be increased substantially to meet rising demand, but it must be achieved with a decreasing impact on the natural resources and environment.

1.2 Challenges

Agriculture, by its very nature, exploits the natural resource base. Despite that awareness of the impacts of modern technologies on the environment has increased, there are those that still argue for further intensification to meet the requirements of agricultural production (Dobbs, 2006). It is in this context that biotechnology emerges as the silver bullet that will revolutionize agriculture with products based on genetic modification methods, making farming more environmentally friendly and more profitable for the farmer. Although certain biotechnological processes hold promise for an improved agriculture, given its present orientation and control by multinational corporations, it also holds more effects for environmental harm, for the further industrialization of agriculture and for the intrusion of private interests which are too far into public interest sector research (Krimsky and Wrubel, 1996). Schoch and McKinney (2003), argue that biotechnology, as a sort of "second green revolution", is being brought forward by the same interests that promoted the first wave of agrochemical-based agriculture, but this time, "by equipping" each crop with new genes, they are promising the world safer pesticides, reduction on chemically intensive farming and a more sustainable agriculture.

These green revolutions suggest the application of scientific research and new knowledge to agricultural practices through farmer education. The theory behind this approach had been the diffusion of innovation models suggested by Rogers (1962). Diffusion studies helped to show agricultural extension workers how to communicate new technologies to farmers and thus how to speed up the diffusion process (Haug, 1999; National Institute of Agricultural Extension Management, 2006). The model of technology transfer is often viewed as a linear model as it assumes a linear relationship between research, extension, and farmer with organized publicly funded science as the source of innovation. This kind of extension models are usually top-down structures, often supported by the ministry of agriculture. The top down structure assumes that only research and support of farmers are needed so that they can make most of its results. Nevertheless, finding solutions to biophysical problems posed by building a sustainable agriculture are scientifically demanding. Hence, we argue that these solutions require new approaches within the imperatives of rural communities facing radical environmental, social, and economic changes. With the concept of sustainability, people mostly think about the environmental or economic sustainability. More attention is now being given to the social component of sustainability, which until recently has been left aside of the sustainability studies (Jorna, 2006). Within the recognition of the new approaches to study, sustainability is the recognition that farmers are (also) knowledge carriers, users and interpreters. In line with the work of Jorna (1992; 2006), we argue that knowledge also exists in the minds of farmers. Farmers can be considered as information-processing systems. This consideration leads us towards a cognitive perspective on knowledge of sustainability. Within this cognitive perspective, knowledge consists of mental representations, which farmers have with regard to their agricultural work and tasks. The methodological problem is that we cannot read the mind of people from the inside.

The link between knowledge and sustainable agriculture is that sustainability requires specific knowledge, what Jorna (2006, 2010) calls Knowledge of Sustainability (KoS). The central issues in Knowledge of Sustainability are the discussions that can be summarized using Elkington´s Triple Bottom Line (TBL) metaphor that explains the impacts that human activities can have in three areas: social well-being and livability, environmental quality, and economic prosperity, also known as the 3P approach People, Planet, and Profit. Farmers as information processing systems can be distinguished not only by the way knowledge is presented in their minds but also by the way the farmer reasons with a specific body of knowledge. Here, lies another methodological challenge since we cannot know either how the representations in the mind of a farmer are processed in order to carry out agricultural tasks. The shift to a knowledge-driven farm will require accepting that farmers can contribute in a knowledge-based society. The top-down approach considers farmers to follow (only) the expert's opinions and to be passive users of information (and knowledge) prepared by others. In contrast, the bottom-up approach sees the farmer to be a "user" and "creator" of knowledge. Farmers must learn from one another and pass along the knowledge they have gained. In the top-down approach, scientific research is the source of farm innovation. The bottom-up approach assumes that technology must not only be effective in the research station, it must be adapted to local conditions, appropriate to farming systems, and desirable by farmers. Therefore, it calls for giving farmers voice by allowing that farmers participate in scientists' projects. We argue that more research and development are needed to apply sustainable agriculture concepts to specific situations and specific problems.

However, unless we move considerably beyond merely doing some additional detailed empirical studies, sustainable agriculture will amount to little more than a faddish but empty slogan. Despite the widespread consensus behind the theory of Knowledge of Sustainability, no knowledge (of sustainability) measurement has been developed to operationalize the theory in a comprehensive way. Heinen (1994) states that sustainability must be operational and that appropriate methods must be designed for its (long-term) measurement. An alternative approach to face the sustainable discussion can be found within the so-called systemic approach. System theory provides concepts and tools to better understand complex developments in agriculture and society, because farming systems are just one type of system in general. Sustainability is a complex term open to a variety of discussions and interpretations. The concept is not an absolute quantity to be measured but it is a concept dependent upon the various perceptions of the stakeholders residing within the context of agriculture (Norman, 2002).

According to Petheram and Clark (1998), farming systems research grew up in the 1970's, partly as a response to the failure of conventional positivist-reductionist research to address the agricultural problems and livelihood strategies of small farmers in the least developed countries. The key elements of farming systems research include an integrated approach, orientation towards the needs of defined target groups, high levels of farmer participation and hence co-learning by farmers and specialists. There is also guidance by facilitators, continuous evaluation, and linkage to policy makers. It is now widely acknowledged that the farming systems research approach made significant contributions to the improvement of agricultural research and education systems throughout the World (Collinson, 2000). The acceptance that there are many different perspectives of reality and that there is a need to understand interdependency and context has emerged from many writers in fields other than agriculture (Checkland, 1981; 1995). Farming systems research calls for an acknowledgement that systems are also constructs of the mind. Systems are therefore ways of viewing the world, systems as wholes have properties that are unpredictable from the known properties of the individual components and linkages between elements and their environment are interdependent and systems may be open or closed (Bawden, 1995).

According to this approach, a view of sustainability should be developed that takes onboard the legitimacy of different views of sustainability. Systems theory is concerned with integration and is designed to take onboard the various viewpoints of actors in a problem context. The need for interdisciplinary thinking has been brought about by the dominance of disciplinary-based thinking which still dominates agricultural educational systems and institutions which are concerned with natural science research (Röling, 1994). Such thinking focuses on expert-based research, on problem solving, on control and manipulation of environments and on designed solutions. In contrast, interdisciplinary approaches address problems within a context, focus on adaptive learning and management, on improving situations, involve teams and coalitions and networks and accept that outcomes are ambiguous, fuzzy and conditional (Jiggins & Gibbon, 1997). Interdisciplinary approaches would seem to be essential for the future of agricultural research as we are dealing with complex, inter-related systems of soil, water, crops, pests, diseases, nutrients, livestock and human resource and farm organization management. For our study, these factors will help us to set the basic premises to develop our approach to understand the reasoning process of the farmers. We also indicate that sustainability is a dynamic process (Hardi and Zdan, 1997; Jorna, 2006) which includes the future of the system in question.

This research sees two challenges for the sustainable agriculture domain. The first is to understand the true nature of agricultural sustainability. It is about the mental representations in the main actors of agriculture regarding sustainability. The second is to understand how these representations are used by the different actors in the agricultural sector, starting with the farmers. This means establishing linkages between the different stakeholders involved in agriculture. Such linkages will further the concept that the path to sustainability does not lie in one single actor, but on multidisciplinary collaboration from a broad range of disciplines (Schoot Uiterkamp and Vlek, 2007). Agriculture has been considered through the years as having the specific function of production where the main objective is to produce commodities (food, feed and fibers) and the main goal has been to increase the land productivity in order to provide more food and to have more economic profit. This model drove the achievements of knowledge in Europe after World War II and it lead to the spread of the Green Revolution in the 1960´s. Nowadays, in the Netherlands, there is an increasing recognition that the current agricultural model requires revision (van der Ploeg, 2009). The agricultural Dutch sector is facing a major challenge, which is the transition towards a sustainable agriculture, including the farm, farmers and natural resources. This sector is facing major challenges, which can affect their entrepreneurial farming activities. The discussion thus far has been at a conceptual, macro level. A more deep approach to sustainability involves examining who is using this term, and how. For example, how does sustainability operate at the farm level? Therefore, it is relevant to investigate the knowledge processes of the main actors in agriculture: farmers. Hence, the objectives of our research are:

- To identify the reasoning patterns, with regard to sustainability, used by farmers to interpret knowledge of this field.

- To study the way the farmers process their representation of knowledge of sustainability.

In this thesis, we argued that the primary goal in conventional agriculture is to increase yield and decrease cost of production. Throughout this dissertation, we argued in favor of a bottom-up approach. This approach provides a basis for planning, deciding, acting and in reacting in specific circumstances. This approach means that the study of sustainable agriculture should start from the individual interpretation of the context. Therefore, it seems to be relevant to understand what knowledge farmers have about sustainable agriculture. It is also relevant to identify mind-settings and reasoning patterns used by farmers to work with this knowledge of sustainability.

1.3 Research Questions

Since we assume that farmers are knowledge carriers, it must also be assumed that farmers have acquired some knowledge to cognitively comprehend the elements and dynamics of their enterprise (farming). Farmers should possess agricultural related knowledge structures that are used to interpret events or to initiate, formulate or recommend plans, projects, or decisions. Despite significant scientific and technological achievements to increase agricultural productivity, there has been much less attention to some of the unintended social and environmental consequences of individual and collective human achievements. Agriculture is one of the key sectors to prevent environmental damage projected to 2030 (OECD, 2008). The European Union -and therefore the Netherlands- now places less emphasis on production than in the past and more on maintaining quality and on the roles and incomes of individual farmers. Agriculture is a system manipulated by humans, and then in accordance with Faber (2006), the functioning of the agricultural system is correlated with the behavior of the humans on whom it depends. Hence, the sustainability of the agricultural system depends on the knowledge of the farmers who determine how the system is functioning. If the meanings of sustainable development are already diverse, some questions arise. In order to achieve the objectives of the research, we elaborated the following research questions:

1) *What is the relation between agriculture, sustainability, and knowledge?*

2) *What kind of knowledge aspects do farmers have regarding sustainability?*

3) *How is it possible to elicit knowledge of farmers?*

   3a)What content of knowledge do (specific type of) farmers have regarding sustainability?

   3b)What reasoning mechanisms do (specific types of) farmers use to favor sustainability?

The complexity of sustainable agriculture requires individuals to possess much knowledge regarding agricultural systems in order to make them behave in a sustainable way. Therefore, local knowledge constitutes an extensive realm of accumulated practical knowledge and knowledge-generating capacities that is needed if sustainability goals have to be reached. This asks for a bottom-up approach, meaning an approach starting from the individual interpretation of the context including the farm, the environment and the farmer himself. Hence, it seems to be relevant to identify reasoning patterns used by farmers to interpret knowledge. Agriculture has been considered through the years as having the specific function of production where the main objective is to produce commodities (food and fibers) and the main goal has been to increase the land productivity in order to provide more food and to have more economic profit. This model drove achievements of knowledge in Europe and the spread of the green revolution beginning in the 1960s. Nowadays there is an increasing recognition that the current agricultural model requires revision. This leads to rethinking the role of knowledge in achieving development and sustainability goals within agriculture.

1.4 Dissertation Outline

This dissertation is structured in order to study sustainability within the context of agriculture with a new approach, a knowledge approach that focuses on the main actor of agricultural systems: the farmer. It is organized into eight chapters (see figure 1.1) which aim at providing the answers to the research questions already posed. The present chapter presents the motivation of the research, the issues that are related, and the research questions that originate. Chapters two, three and four present the theoretical background. Chapter 2 discusses the evolution of the agriculture through time. It has special emphasis on the Green Revolution and in the future of agricultural systems. Chapter 3 refers to the concept of sustainability. It describes the systemic perspective towards agriculture on which we base this research. Chapter 4 explains the relevance of knowledge (in agriculture) in various operationalizations. It introduces the conception of farmers as human information processing systems, which is our departure point to develop the conceptual model. In Chapter 5, we develop the conceptual model of the research. It discusses knowledge as a core element to study sustainability. It also introduces the different variables that will be examined in the empirical study. Chapter 6 presents the methodology that was used to achieve the research objectives of our study. Chapter 7 discusses the data. The thesis concludes with chapter 8 reflecting on the findings as well as on the contribution made to the fields of agriculture, sustainability, and knowledge management. It also presents the implications for future research.

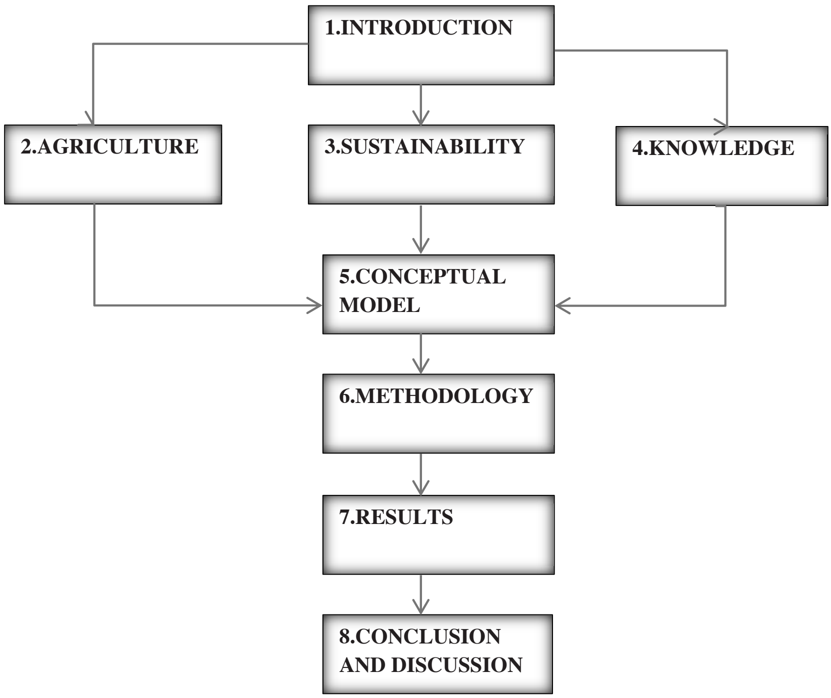


Fig. 1.1 Dissertation outline

2 AGRICULTURE

2.1 Introduction

In Johannesburg summit 2002 five key themes were identified - water, energy, health, agriculture and biodiversity (UN, 2011). In our study, we explicitly aim at a contextual rather than at a generic study of sustainability (see chapter 3). We situate our study in the context of agriculture. In the present chapter, we discuss the need to consider and plan for the effects of conventional agricultural practices. Conventional agriculture creates diverse challenges that require a strategic reappraisal of how to continue with the farming practices. Sustainability has developed into an important issue on the international agenda and agriculture is not the exception (see chapter 4). We argue in favor of sustainability as a guiding principle to master the challenges that agriculture faces. Hence, it is appropriate to consider the role of knowledge management in these challenges. The focus of attention is knowledge at an individual level (see chapter 5). We will start by discussing agriculture in more detail.

Agriculture as the source of human food, animal feed, fiber, and fuel has played a key role in humanity history. The history of agriculture is visible to us due to archaeological studies as well as for research related to foraging societies (Tauger, 2011). Its development has been driven and defined by different climates, cultures, and technologies. However, all farming generally relies on techniques to expand and maintain the lands suitable for raising domesticated species. Agriculture is a major occupational sector for approximately 2.6 billion people worldwide, be it farming, livestock production, forestry or fishery (FAO, 2000). Food security for a growing world population is positioned to remain a challenge in the next few decades (IAASTD, 2009). The Agricultural sector is the largest user of water and is responsible for much of its pollution (UNEP, 2008). The OECD projects three main trends in the agricultural sector 1) The world primary food crop production to grow by 48% and animal products by 46% to 2030. 2) If no new policies are introduced, the conversion of natural land to agricultural use will continue to be a key driver of biodiversity loss. 3) Under current policies, areas for biofuel crops are projected to increase by 242% between 2005 and 2030 (OECD, 2008). In the old member states of the European Union (EU15) particularly in the Netherlands, where we focus our study, as a reaction to the food shortages during and after World War II, the EU's Common Agricultural Policy (CAP) initially encouraged the production of food surpluses in order to reach self-sufficiency (Agricultural Economics Research Institute, 2006; SER, 2006). The more farmers produce the more financial support they received. Over time, this policy created over-supply at a high cost to the taxpayer and sometimes had the effect of channeling funding to farmers who did not really need it (European Commission, 2011). A recognition of this problem coincided with growing worries about whether the CAP was encouraging intensive farming methods that had implications for the environment and food safety (Agricultural Economics Research Institute, 2007). As a response to the encouragement of the use of intensive practices, EU has attempted to ensure an economically efficient and environmentally sustainable agriculture. Therefore, agriculture will remain to be of importance for the management of the land and the environment. (van Meijl et al. 2006; Rienks, 2008; Westhoek et al., 2006; Verburg et al. 2006).

2.2 Agricultural Systems

Mannion (1995) defines agriculture, or farming, as the production of crop plants through cultivating the soil and the rearing of animals. This definition points out that agriculture requires modification of the environment in which it is practiced. Nowadays, agriculture also produces food for livestock and poultry, fibers used in several industries and recently it has been seen as one source of biofuels such as ethanol, biodiesel from soya-beans and fuels derived from cellulose (Runge and Senauer, 2007). Farmers contend with the biophysical environment, emerging technologies and cultural traditions. Thus, the management environment of a farmer is a complex interaction between biophysical and socio-economic factors that are constantly changing and are often conflicting. A systems approach provides a convenient overview and understanding the interaction among these factors. Note that the following traits of the agricultural system have important implications, which are further elaborated in chapter three. Systems can be regarded as a group of interacting components within boundary, which operate together for a common purpose (Richmond, 2005).

Systems can be arranged in a hierarchy of complexity and components in high-level systems can be regarded as sub-systems (Simon, 1968; Meadows, 2008). The level and nature of the components vary with the scope of the system being described, its purpose, and the interest of the observer. The boundary does not need to be a physical boundary, rather a conceptual boundary that ensures that all the important components are included in the description of the system. An agricultural system can be composed of the soil, animals, farmers, the rural community, government, the market, plants, and advisors. Inputs refer to resources such as energy flows, labor, money, and knowledge. Outputs can be quantitative expressions about matter flows such as yield, earnings, or wastes. Outputs may also include qualitative expressions such as rural heritage or well-being (figure 2.1). A special characteristic is that humankind (e.g. by means of differences in agricultural techniques) influences inputs and processes. Most of the outcomes are used for human consumption and only in some cases they are reused within the agricultural system (e.g. use of manure in the soil). Agriculture is an activity where the farmer is the main sub-system but because it involves other sub-systems a holistic view, which is one of the foundations of systems approach (Meadows, 2008), provides to be key in the understanding the interactions among the different parts of the system. Another systems trait is openness (Jorna, 2006). Openness refers to whether a system is isolated from other systems. An open system is not isolated in that it exchanges matter, energy, or information with other systems. A closed system is isolated and exchanges nothing. An agricultural system is an open system because, as we discuss in chapter three, it is a part of a bigger system and interacts with it.

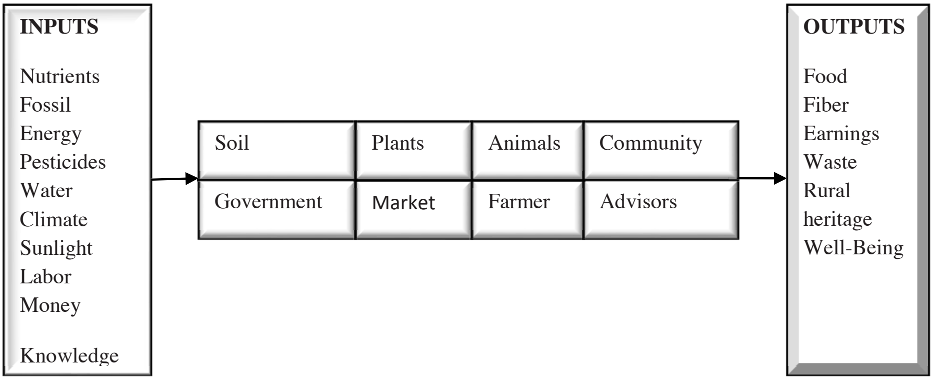


Figure 2.1 Schematic representation of an agricultural system

2.3 Brief History of Agriculture

Agriculture has varied considerably across time and space. Agriculture has no single, simple origin. A wide variety of plants and animals has been independently domesticated at different times and in numerous places. Mazoyer and Roudart (2006) and Tauger (2011) perform concise studies on the history of agriculture and show how it has developed in different regions of the world through the years. Humans began to alter wild habitats in productive ways long before they developed writing systems. It is thought that—at least initially—the new animals and plants that were developed through domestication may have helped to maintain ways of life that emphasized hunting and gathering by providing insurance in lean seasons. The transition from hunting and gathering to full-fledged farming is important throughout many parts of the world, but the period of initial domestication and the gradual shift to a full farming economy are ill-defined (Smith 2001). This transition is also known as the First Agricultural Revolution (Baker, 2011). Farming, as the intensive use of domesticated plants and animals, developed independently from an earlier stage of experimentation in many parts of the world. For example, the first species to be domesticated was the dog to be first used as an aid in hunting. Similarly, the domestication of plants also occurred in several different places. In Asia, people of the Far East domesticated rice and soybeans, after millet. However, the earliest domestication of plants and animals appears to occur in the Near East. Archaeologists have long asked why there was a shift from hunting and gathering to a settled lifestyle in many parts of the world after the last glacial period. The answers are debated, but for the Near East, climate is an important factor. Following the last glacial maximum, changes in the expansion and contraction of the vegetation belts are demonstrated by pollen sequences. The changes are driven by decadal and centennial quantities of precipitation, rather than just temperature (Bar-Yosef and Belfer-Cohen, 1992). The pluvial conditions peaked around 11500 BC, resulting in a combination of a large number of periodically reliable stands of grasses with large grains. This encouraged an increase in population and greater sedentism, social complexity and territoriality (Bar-Yosef and Maedow, 1995). Estimates imply that the resulting Neolithic agricultural practices produced greater yields than those of unattended wild cereals (Araus et al. 2001).

2.3.1 The Earliest Domesticates in the Near East

Bar-Yosef (1992) concluded that cereal harvesting reached back 12 000 – 10 000 years ago. Plant research shows that wheat, barley, chickpea, pea, and lentils occurred together in an area around the upper Tigris and Euphrates River (Lev-Yadun, et al. 2000). The distribution of wild animals overlaps with the core area of plant domestication. Wild sheep and goat are confined to Western Asia (the Near East), the distribution of cattle and pigs ranges from the Atlantic in Europe to the Pacific in the Far East.

2.3.2 Spread of Near Eastern Agriculture to Central Europe

Agriculture spread through complex interactions between resident hunters and gatherers and agricultural peoples who were migrating into the region. Todorova (1998) argues that continued climate changes drove the expansion of the farming based economy from Palestine via Anatolia to the Balkan Peninsula. It is currently accepted that agriculture reached Central and Western Europe by two routes. One agricultural movement from the Near East reached the Mediterranean Coast of Italy and France a northward progress from these pottery-using groups unfolded around 6000-5600 BC (Binder, 2000). The other general route seems to have led from the Near East, probably across Greece to Hungary. The evidence implies that there was a roughly simultaneous switch to domesticate in Central and Western Europe around 5500 BC. This period seems to be a critical phase for the spread of farming into the central latitudes of Europe, leading to a meeting of eastern and western agriculturist. The genesis of the first full-fledged farmers of Central Europe is sought in Transdanubia, western Hungary, and adjacent regions of the Danube Basin. These Danubian farmers existed between about 5700– 5000 BC. They are known primarily by the German term "Linienbandkeramik" abbreviated (LBK). Literally translated this means Linear Band Pottery. The name stems from the characteristic design of linear bands gracing the early pottery. The culture is now usually referred to simply as Bandkeramik. The Bandkeramik farmers used domesticated plants, including emmer and einkorn wheat, barley (more in the east than in the west), peas, flax, and poppy. Millet and lentil are identified (Jochim, 2000). According to Bogucki (1995) cattle predominate, but sheep and goat were also kept. Very few pigs and wild animals appear in the archaeological record. However, in Hungary and Austria sheep predominate in early sites. By 5000 BC, farming was common in Western Europe.

2.3.3 Agriculture in the West (300 BC until 1900 AD)

Crop farming and domestication of animals were well established in Western Europe by Roman times. Yields per acre were small by 21st-century standards, and nearly half the annual crop had to be used as seed, but quantities of grain were still exported from Britain to Gaul. Farming techniques were dictated to some degree by the Mediterranean climate and by the contours of the area. The majority of the crops cultivated today on the Mediterranean coast—wheat, spelt, barley, some millet, and legumes, including beans, peas, vetch, chickpeas, alfalfa, and lupines were known at that time. Grapes, olives, radishes, turnips, and fruit trees were grown. Roman holdings were commonly as small as 0.5 hectare; the ground was prepared with hand tools, hoes, and mattocks edged with bronze or iron. Most Roman-era hand tools were similar in shape to their modern counterparts. The wooden plow was fitted with an iron share and, later, with a cutter (Redman, 1978). The medieval period can be divided in two periods in order to study agricultural developments. The first period lasted until the end of the 13th century (Tauger, 2011). The most important agricultural advances took place in the countries north of the Alps. The climate and soils and, perhaps, the social organization compelled different arrangements of land division and the use of more-complex tools as more and more farmland was converted from forest, marsh, and heath to meet the needs of a rising population. The second period began toward the end of the 13th century. The disasters of the 14^{th} century—climatic, pestilent (the Black Death), and military (the hundred year's war)—followed. The result of all these misfortunes was to be seen in the landscape throughout Western Europe. Much of the arable land could not be cultivated for lack of laborers; in some regions, a few scattered peasants inhabited the countryside. Many of the settlements were abandoned and they became deserted villages.

After the discovery of America in 1492, a global exchange of previously local crops and livestock breeds occurred. Key crops involved in this exchange included the tomato, maize, potato, manioc, cocoa bean and tobacco going from the New World to the Old, and several varieties of wheat, spices, coffee, and sugar cane going from the Old World to the New. The potato became an important crop in northern Europe (FAO, 2008). Since being introduced by Portuguese in the 16th century, maize and manioc have replaced traditional African crops as the continent's most important staple food crops (Nweke et al., 2007). The Second Agricultural Revolution coincided with the Industrial Revolution (Thompson, 1968). Farming started to become mechanized and commercial with the development of new inventions and technology (tractor, seed drill). By the early 19th century, agricultural techniques, implements, seed stocks and cultivar had so improved that yield per land unit was many times that seen in the Middle Ages. The work of Charles Darwin and Gregor Mendel created the scientific foundation for plant breeding that led to its explosive impact over the 20th century (Kingsbury 2009). Around 1840, Justus von Liebig debunked the humus theory and made a scientific case for plant requirements for mineral elements from the soil, carbon from CO_2 in the air, and H and O_2 from water (Gillispie, 1990). Liebig developed the first mineral fertilizers applied to replenish nutrients removed from soils by crops. Liebig's "Law of the Minimum" states that yield is proportional to the amount of the most limiting nutrient, whichever nutrient it may be (van der Ploeg et al., 1999). From this, it may be inferred that if the deficient nutrient is supplied, yields may be improved to the point that some other nutrient is needed in greater quantity than the soil can provide, and the Law of the Minimum would apply in turn to that nutrient. Liebig made great contributions to the science of plant nutrition and soil fertility that will be used as a basis for the agricultural developments in the century to come.

2.3.4 Conventional Agriculture (Twentieth Century)

Agricultural technology developed more rapidly in the 20th century than in all previous history. During World War I, farmers benefited from high prices, which persisted for a short period after the war because of a shortage of food supplies (Kjeldsen-Krag 2007). In 1909, Haber managed to solidify nitrogen in a useful and stable form for the first time (Smil, 2001). What Haber did was the process of obtaining ammonia by combining hydrogen and nitrogen a high temperature and pressure in the presence of a catalyst like iron oxide. The following industrial application of the process by Carl Bosch permitted the agricultural independence of Germany when, during the First World War, the allies blocked supplies of organic nitrate. The two chemists received Nobel prizes for their Haber-Bosch process. European agriculture recovered from wartime losses in land fertility, livestock, and capital and by the early 1920s was fully productive. Elsewhere, production had expanded greatly during the war and afterward continued to rise. After the war prices declined, and, as farmers sought to compensate by expanding their output, the fall in prices was aggravated. Agricultural tariffs, generally suspended during the war, were gradually reintroduced. The Great Depression of the 1930s brought a new wave of protectionism, leading some industrial nations to look toward self-sufficiency in food supplies. During World War II, agricultural production declined in most of the European countries, shipping became difficult, and trade channels shifted. By the end of World War II, food production in most of the countries of Europe had fallen below the prewar level. The internal combustion engine brought major changes to agriculture in most of the world (Rasmussen, 2010). In advanced regions, it soon became the chief power source for the farm (Fussell, 1965). Trucks have changed patterns of production and marketing of farm products. Trucks deliver such items as fertilizer, feed, and fuels; they also go into the fields as part of the harvest equipment; and haul the crops to markets, warehouses, or packing and processing plants. Maize and cotton pickers came into use in the U.S. after World War I and they were even more widely adopted after World War II. The self-propelled mechanical tomato harvester was developed in the early 1960s (Encyclopedia Britannica, 2011). Over the past three decades, societal demand has grown for agricultural products that carry fewer risks for human health and environmental pollution. A concept that has being articulated is 'sustainability',i.e., aiming for an agricultural system being more environmental-friendly, economically viable and socially acceptable. We argue that understanding sustainability requires the study of different knowledge aspects of multiple stakeholders but especially of the farmers since they are at the core of the farming practices.

2.4 Agriculture in the Netherlands

The Netherlands is both a major producer and international trader of flowers, meat, and meat products, fruit and vegetables, beer, dairy products, chocolate, starch derivatives and seed (Ministry of Agriculture, Nature and Food Quality, 2008). The Dutch rank third worldwide in value of agricultural exports, behind the United States and France. Dutch agricultural exports are derived from fresh-cut plants, flowers, and bulbs, with the Netherlands exporting two-thirds of the world's total. The Netherlands also exports a quarter of all world tomatoes, one-third of the world's exports of cucumbers, and one-fifteenth of the world's apples (Food and Agriculture Organization of the United Nations, 2007; Ministry of Agriculture, Nature and Food Quality, 2007). In its policy presentation for 2010, the Ministry of Agriculture, Nature, and Food Quality divided its policy into four areas: 1) sustainable production 2) knowledge and innovation, 3) food, animal and consumer and 4) landscape and rural environment. Within sustainable production, extra attention will be devoted to improving sustainability in the fishery sector. Within the knowledge and innovation domain the goal is to ensure that green education is better aligned to the labor market.

2.4.1 Historical development

Bieleman (2010) performs a concise study of the development of Dutch agriculture for the period 1500 - 2000. As soon as the first people settled in what it is now the Netherlands, the restructuring of the countryside began. People cultivated the land and they created a surplus, which permitted the founding of villages, and towns, where people with other occupations settled. The construction of dikes was an important instrument for the prevention of floods. The associated wind technology was important as well. This processes transformed the fenland in the west and the north of the Netherlands into lakes and pasture, while moorland was turned into arable land. Around 1900 the Dutch territory was not densely populated, it supported almost a third part of today's population (five million inhabitants). The limited options offered by technology resulted in a sound use of water and land. Moreover, agriculture was small scale, and individual owners inhabited most country estates. Farmers proved to be of enormous value to the food supply during the Second World War. According to Somers (1996), sociologists in the 1960's in the Netherlands commented the agricultural transition as a process of acculturation to a different lifestyle. The new life style not only included a new farm management approach but also a new complex of norms and values, attitudes and behaviors. After the war, they received the support of the government in its effort to attain food security. There were stimuli for farmers to expand their farms within the new economic structure, while small farmers obtained the option to liquidate their activities.

Dutch agriculture was influenced by the Common Agricultural Policy (CAP) of the former European Economic Community (Social and Economic Council in the Netherlands, 2008). The CAP focused almost entirely on providing a policy framework for increasing agricultural production and encouraging agricultural intensification. This framework policy was aimed at increasing production of agricultural commodities, it was closed to strong financial state support, and intervention through farms subsides, price guarantees, and protectionist and interventionist policies that kept prices for agricultural products artificially inflated since the 1960's, giving farmers a strong sense of financial security. The work from Junkema and van der Waal (2007) and literature review made for McElwee (2005) note the importance of the common agricultural policy, globalization, and Europeanization for the Dutch agricultural sector. In the 1990's the Ministry of Agriculture started to consider a new focus for the agricultural sector as an alternative for farmers who could not cope with the industrial mode of production in Agriculture. Farmers were threatened by the European Union's revision of its agricultural policy –from interventionism to a free market system – that in most cases resulted in a fall in incomes (European Commission, 2007; Rienks, 2008). To remedy this, farmers tended to turn to solutions, which had been successful in the past – intensification, extensification, or specialization in new activities. Since the first two solutions were undesirable because of problems with manure and the scarcity of land, the third solution was promoted. The government provided financial stimuli for additional activities such as nature management, the growing of flowers or fish farming, running camping sites or bed-and-breakfast at the farms, the provision of care for the elderly or the disabled, and so on. Additional attention was paid to regional products and to the development of regional farming styles (SER, 2008). The agricultural sector is of real importance to the Dutch economy and culture (Agricultural Economics Research Institute, 2006). The Agricultural Economics Research Institute reports from 2006 to 2011 show the trends in the Dutch agricultural sector. We summarize these trends in three areas: social, economic and environment.

- **Social Factors**

The farming areas employed around 141 000 persons in 2010 (Agricultural Economics Research Institute, 2011). The sector consists of numerous micro-, and small to medium sized enterprises. Over 60% of the area covered by the Netherlands is defined as rural. Between 2000 and 2010, the number of farms in the Netherlands declined from 97,000 to 72,000. The decline in employment in agriculture has meant that the agricultural working population in most country areas has become a very small group. This decline in the farming population may result in farmers having less influence on local decisions regarding spatial development, despite the fact that they still own the majority of the land in the countryside (Agricultural Economics Research Institute, 2010). The educational level of the Dutch farmers and growers is still improving: in 1996, 46% had a secondary or higher level of education; this figure had already risen to 65% in 2005. In general, the potential business successors have a higher level of education than the current heads of the businesses (Agricultural Economics Research Institute, 2006).

- **Economic Factors**

Rural areas are changing in appearance as non-farmers who use the land for hobby-agriculture and building (second) homes or business premises are buying more land. In addition, agricultural land is being turned into nature and leisure areas (Agricultural Economics Research Institute, 2008). A larger area, however, is lost as open land by being incorporated into built-up areas. In 2009, the amount of farmland area was approximately 1.9×10^6 hectares (LEI, 2010). Of the total acreage of cultivated land, 53% is now in use as grassland (permanent, temporary, and natural grassland), 12% for green maize, 30% for other arable land, 4.5% for open field horticulture, and 0.5% for greenhouse horticulture. The average price of agricultural land raised from 29,000 Euros per hectare in 2006 to 42,900 Euros in 2009 (LEI, ibid.). The strong rise in the price of agricultural land is related to both national and international developments. Because of increased global demand for agricultural products - partly for bio fuels - in times of short supplies, the prices for grain and milk have soared. The high price of milk has given Dutch dairy farming more financial scope to invest in land (Agricultural Economics Research Institute, 2009).

The European Union (EU) aims at placing emphasis on maintaining quality and on the roles and incomes of individual farmers than on only (high)production yields (Rienks, 2008; SER, 2008). For example, the EU provides support for farmers who take part in schemes designed to improve and assure the quality of agricultural products and production processes (European Commission, 2007; Social and Economic Council of the Netherlands, 2008). De Lacroix (2004) suggests that the actual agricultural policy of the European Union is barely recognizable when compared to pre-1990's period. The agricultural policy has been simplified with the array of different direct payment schemes into a single farm payment. It also has more efficient mechanisms, meeting more objectives at a lower cost. In the 1990's the agricultural policy absorbed two thirds of the total EU budget. It is expected that by 2020 the agricultural policy absorb just one-third of the EU budget (SER, 2008). Its scope is constantly widening following the introduction of a comprehensive rural development policy that supports the diversification, restructuring, and evolution of rural areas and economies throughout the European Union.

- **Environmental factors**

The Netherlands increased chemical inputs between the 1950's and 1980's enabling the country to intensify agricultural production to such an extent that by 1990 it was able to produce 9% of the EU's agricultural exports on only 2% of the EU's land area (Jongeneel and Ge, 2005; Agricultural Economics Research Institute, 2007). Increase in the quantity of agricultural commodity production was achieved through increase in the use of artificial fertilizers to make up for rapid nutrient losses caused by intensive farming. The increase in these inputs to the agricultural systems is associated with harmful polluting effects on diverse ecosystems. It has had substantial impact on soils through soil pollution linked to increased use of chemical inputs, soil compaction using heavy machinery, and soil erosion and salinization through intensive irrigation. It should be noted that changes in actual use are partly caused by weather conditions, a relatively "wet" year like 2007 leads to a higher use (Agricultural Economics Research Institute, 2008). Although the use of chemical agents increased in the 2001-2006 period, the environmental impact on the soil and the ground water diminished as old agents with a high environmental impact were replaced by newer, more environmentally-friendly chemical agents. As a result of this, all stakeholders signed an agreement in 2004, called the Sustainable Covenant on Crop Protection (Ministry of Housing, Spatial Planning and the Environment, 2006). This agreement aimed at reducing the environmental risks, caused by pesticides, with 95% in the year 2010 compared to 1998. It is not yet certain whether all targets specified in the Sustainable Covenant on Crop Protection were achieved by 2010. One of the targets, a reduction of the environmental impact of the surface water by 95% in 2010 compared to 1998, seemed to be unattainable. The reduction in 2009 was around 85% (Agricultural Economics Research Institute, 2010).

2.4.2 Future of the Dutch Agriculture

Despite significant scientific and technological achievements to increase agricultural productivity, there has been much less attention to some of its unintended and environmental consequences. Due to these consequences the future (if not the present) of the Dutch agricultural sector is to transit towards a sustainable pathway (Poppe et al., 2009, Agricultural Economics Research Institute, 2011). According to Slingerland and Rabbinge (2009) agriculture in the Netherlands faces challenges that are part of this transition:

- Find a balance between economic, ecological, and social factors;
- Cope with social resistance to actual technical and economical rationality;
- Perform well according to the complex national, European, and global legal framework;
- Have a competitive position in the global market.

The previous challenges cover multiple domains and combine processes that occur at different levels of scale. Agriculture became industrialized due to the knowledge developments of the 20th century. After the Second World War, agriculture has developed into a highly productive sector. The knowledge infrastructure has contributed strongly to achieving that position. Nevertheless, productivity and economic profit are no longer sufficient. Agriculture is not an isolated system and it has to contribute to other areas such as biodiversity conservation, environmental issues, and attractive rural area for the urban population. Coping with these challenges demands the recognition that knowledge is developed and used by farmers (National Council for Agricultural Research, 1998; van der Ploeg, 2009). Furthermore, one discipline is not enough to address these challenges (Schoot Uiterkamp and Vlek, 2007; Jorna, 2010). These challenges call for an interdisciplinary and multidisciplinary approach as we discuss in chapter 3. The traditional linear model that functioned in the Netherlands (research-extension-education) is being replaced by a more participative approach (see section 4.2) where there is a need to understand which knowledge structures farmers have and use with regard to agricultural practices. The effectiveness of the participative approach depends largely on the ways in which the knowledge of sustainability is processed by practitioners, farmers and other agricultural stakeholders. Moreover, outcomes of agricultural research may also be applied to support policies related to sustainable agricultural development and the management of natural resources.

2.5 Effects of Agriculture

Mckinney and Schoch (2003) explain the (natural) process of ecological succession where the successive groups of plants and animals will colonize a portion of land. The first settlers will generally be smaller, fast growing and pioneer plants. Then larger, slower growing, and longer-lasting plants will progressively replace the original colonists. The final stage of succession is the climax community. In the climax stage, much of the energy and nutrients go into maintaining the system; the only new growth that occurs replaces plants that die. In a mature, climax ecosystem, the complex relationships and interactions among many species of plants and animals promote long-term stability. There are natural balances on predator-prey relations, diseases, and population explosions of particular species. Climax ecosystems are also less susceptible to the ravages of climatic fluctuations such as droughts and floods. These ecosystems are characterized by complementary relationships between organisms: the nutrients extracted by one organism are eventually passed on to and restored by another organism. The [natural] cycle of growth, death, decay, and re-growth ensures continued recycling of raw materials. Replenishing occurs naturally during later stages of ecological succession.

Agriculture alters and manipulates ecosystems, transforming them into artificial ecosystems that are inherently unstable and require constant human attention. In this artificial ecosystem, when the land is cleared for agricultural purposes, the cycle of succession begins anew. However, the process does not follow the natural course and reaches a climax. Instead, the land is artificially maintained at the pioneer stage; furthermore, the pioneer plants that are allowed to grow on the land are carefully picked, maintained, and managed. An ecosystem is most productive at the pioneer stage of succession. In this stage, almost all the energy and nutrients are utilized into the growth of plants. This characteristic of pioneer ecosystems make modern monoculture farming productive and successful on a short-term basis but they cause continued environmental degradation in the long-term. Pioneer stages extract a heavy toll of nutrients from the soil without replenishing them. Rapid nutrient absorption without recycling destroys the soil's fertility. Lack of balanced vegetation- or not vegetation at all between harvesting and the next planting season- to hold the soil in place and absorb moisture can lead to massive erosion of valuable topsoil, flash floods, dust storms, and droughts. In fertile areas, the soil may take half a century to become severely damaged (longer than the individual farmer may stay in business). When soil is damaged and not suitable for growing crops, farmers would classically move on new land. However, there are traditional methods of coping with agriculture's effects like occupying the land for a year or two, often cutting and burning the natural vegetation in order to clear the land and release the nutrients into the soil, and then move on. In this way, the natural ecological cycle of succession can occur once again; the land is allowed to regenerate and replenish itself. This method is feasible as long as the number of farmers in any given area is relatively small, and they are willing to move on a regular basis without considering any land ownership issues. In Agricultural techniques of the late 19th century through 20th century were developed to cope with the problems in the pioneer stage of ecological succession. These techniques are also known as conventional agricultural practices and shape the model known as Green Revolution, which we examine in the next section.

2.6 The Green Revolution

The green revolution refers to the breakthroughs in research into new varieties of maize, wheat, and rice that with a set of complementary inputs may result in dramatic increases in the yields per harvest. It is also called the Third Agricultural Revolution ( ). When new varieties shorten the crop cycle from sowing to harvesting, the green revolution also allows for more crops per year and thus contributes to further intensification of agriculture and increase of output per unit of land. The green revolution in Asia doubled cereal production there between 1970 and 1995, yet the total land area cultivated with cereals increased by only 4 percent (Rosegrant and Hazell, 2001). By dramatically slowing the expansion of cultivated area, agricultural intensification has also preserved forests, wetlands, biodiversity, and the ecosystem services they provide (Nelson and Maredia, 1999). Nevertheless, intensification has brought environmental problems of its own. In intensive cropping systems, the excessive and inappropriate use of agrochemicals pollutes waterways, poisons people, and upsets ecosystems. Wasteful irrigation has contributed to the growing scarcity of water, the unsustainable pumping of groundwater, and the degradation of prime agricultural land. Intensive livestock systems, part of the continuing livestock revolution, also present environmental and health problems. High concentrations of livestock in or near urban areas produce waste and can spread animal diseases, such as tuberculosis and avian bird flu, with risks for human health. In areas not affected by the green revolution, there has been little if any agricultural intensification; instead, agriculture has grown through extensification—bringing more land under cultivation. This has led to environmental problems of a different kind—mainly the degradation and loss of forests, wetlands, soils, and pastures. Every year about 13 million hectares of tropical forest are degraded or disappear, mainly because of agriculture. Some 10–20 percent of dry lands may suffer from land degradation or desertification (Millennium Ecosystem Assessment 2005).

The positive characteristics of the Green Revolution (Szirmai, 2005) are:

- Increased yields per crop. In addition, the rapid maturing of dwarf varieties allowed for more harvesting per year;
- The development of new plant varieties with high yields that have been adjusted to local conditions;
- Land-saving innovations;
- Use of industrially manufactured fertilizers, pesticides, and herbicides;
- Increased volume of investments in agricultural research;
- The organization of an effective system of agricultural extension;
- Investments in irrigation and water control;
- The development of delivery systems for new seeds and inputs;
- The development of credit institutions and facilities, which enable farmers to purchase new inputs;

- Complementarities between the different inputs: research, new seeds, industrial inputs, education, delivery, and credit facilities.

However, the downside of the Green Revolution is that the massive application of modern agricultural techniques has resulted in numerous problems (Mannion, 1995; McKinney and Schoch, 2003; Kassie and Zikhali, 2009; IAASTD, 2009) as:

- Soil degradation is increasing rapidly as nutrients are extracted from the soil but not returned in kind;
- Creation of negative feedback loops. For example, inorganic fertilizers lose effectiveness when the organic matter of the soil is low, which is of particular concern in soils where there is a continuous cultivation and degradation of arable land;
- Adverse irrigation effects such as salinization and water logging;
- Depletion of groundwater supplies due to pollution from herbicides and pesticides;
- Adverse human health and environmental impacts due to inappropriate and excessive use of chemical agents;
- Biodiversity loss by killing beneficial plants and insects;
- Use of genetically modified organisms that might be adverse to human health;
- Increase in rural inequality due to increasing landlessness and to impoverishment of the rural masses. Large farmers have better access to new inputs like better training and education than small peasants do;
- Farmers become more and more dependent on a few agricultural multinationals. The position of small farmers is threatened by the increasing cost of inputs.

In order to diminish the effects mentioned above some changes are necessary. For example, reduction in pollution, increase in nature conservation and improvements in working conditions. To promote this changes knowledge is needed. What is therefore needed is knowledge content about the agricultural system and the knowledge by which such changes can be achieved. In the following, we describe in detail some of the negative effects caused by conventional agricultural practices.

2.6.1 Soil degradation

For decades, modern agricultural technologies have masked the soil deterioration by increasing yields even as the soil has become degraded. Techniques such as drip irrigation, and crop rotation can mitigate or prevent soil degradation (Tripp, 2006). In a fertile area, the soil may take fifty years to become severely degraded – longer than the individual farmer may stay in business. Classically, the next generation would move on to new land, but the world is running out of new land to farm (Bruinsma, 2003). Soil conservation practices should be a prime target in sustainable agricultural systems. As simple as it sounds, without soil humanity could not grow food. Soils are complex physical, chemical, and biological systems, which are subjected to constant change through the influence of weathering, soil organisms, and vegetation but above all through the economic activity of human beings (McKiney and Schoch, 2003).

Soil is layered into sections called "horizons" (College of Tropical Agriculture and Human Resources, 2011). The figure 2.2 shows a typical soil profile. The top horizon (“O” horizon) is composed of *humus* and contains most of the organic matter. This layer is often the darkest.

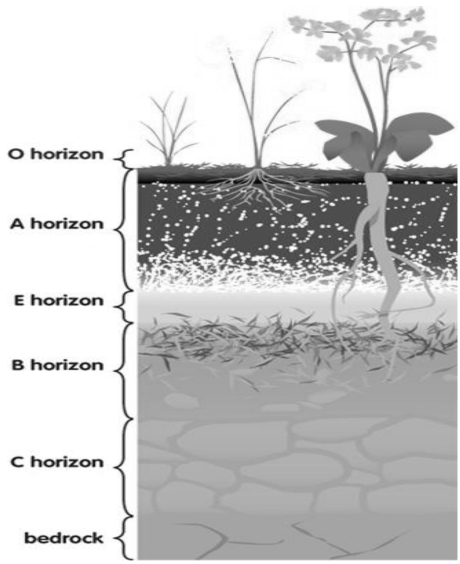


Fig. 2.2 Typical soil profile

The "A" horizon consists of tiny particles of decayed leaves, twigs, and animal remains. The minerals in the A-horizon are mostly clays and other insoluble minerals. Minerals that dissolve in water are found at greater depths. Layers “O” and “A” form the top soil. It mixes rich humus with minerals and composted material, resulting in a nutritious substrate for plants and trees. The “E” horizon is the eluviation (leaching) layer is light in color; this layer is beneath the A Horizon and above the B Horizon. It is made up mostly of sand and silt, having lost most of its minerals and clay as water drips through the soil (in the process of eluviation). The "B" horizon has little organic material, but contains the soluble materials that are leached downwards from above. The "C" horizon is slightly broken-up bedrock, typically found 1-10 meters below the surface. While this is a typical soil profile, soil types exist, depending on climate, local rock conditions and the community of organisms living nearby. The bedrock or “R” horizon is the bedrock layer that is beneath all the other layers.

It takes (on average) about 100 years to generate a millimeter of soil (University of Michigan, 2011). Soil fertility is influenced by the factors of soil formation. As soils, form nutrients are being continually removed from and added to the soil with time. The conditions that are present during soil formation ultimately determine how much and what kind of nutrients the soil can naturally supply and hold. There are essential elements that plants must have in order to grow properly (Barker and Pilbeam, 2006). Nutrient elements obtained from atmosphere through photosynthesis (hydrogen, carbon, and oxygen). Nutrient elements obtained from the soil are divided into 3 groups: primary, intermediate, and micronutrients. The primary nutrients are nitrogen, phosphorus, and potassium. They are required in larger quantities than other nutrients. The intermediate nutrients are sulfur, magnesium, and calcium. Together, primary and intermediate nutrients are referred to as macronutrients. Macronutrients are expressed as a certain percentage (%) of the total plant uptake. The remaining essential elements (iron, boron, manganese, zinc, molybdenum, copper, cobalt, chlorine and nickel) are the micronutrients and are required in very small quantities. In comparison with macronutrients, the uptake of micronutrients is expressed in parts per million (ppm, where 10,000 ppm = 1.0%), rather than on a percentage basis. Since the soil provides most essential nutrients, it is crucial to understand the soil processes that determine the availability of each essential nutrient for plant uptake.

Soils are the interaction point of two basic biotic processes of terrestrial ecosystems: 1) the generation of biomass by green plants from CO2, water and salts with the help of solar energy (production), and 2) the subsequent breakdown (decomposition) of this biomass through the uptake of O2 by consumers and decomposers and the release of nutrients, trace elements and CO2 (ISRIC, 1990).The German Advisory Council on Global Change (1994) describes four basic functions of soil:

- Habitat Function: Soils are the basis for life for a wide variety of plants, fungi, animals, and microorganisms. Soil organisms are responsible for the synthesis, conversion, and decomposition of organic substances in soils;

- Regulation Function: This function includes the accumulation of energy, carbon and substances, as well as their transformation and transportation. It comprises all abiotic and biotic processes that take place in the soil;

- Utilization function: This term is directly linked to the functions that people deploys in a “gainful” way to satisfy their needs. It includes the following sub functions: production function (it refers mainly to the deliberate utilization of soils for agricultural, forestry and exploitation of natural resources such as oil or coal), Carrier function (it includes the sue of soil for settlements, transport and disposal of waste) and the Information function (It comprise the uses of soil as an indicator for their fertility, mechanical stress-bearing capacity, and usefulness in general);

- Cultural Function. - Soils are the basis for human history and culture. The quality of soil has exerted an influence on the forms of economy and settlement as well as on the social structures. It also has determined a legal basis in order to distribute land and the forms of settlements that are developed. Some religious bonds to soil are linked to the fertility.

When people interfere with soils, much degradation occurs and the functions are altered. Anthropogenic soil degradation is defined as a permanent or irreversible change in the structures and functions of soils or its loss. The change is made by physical, chemical, or biotic stress induced by humanity, which exceeds the stress-bearing capacity of the respective systems (ISRIC, 2011).

ISRIC (ibid.) describes the main types of soil degradation:

- Water and wind erosion.- Erosion is the term given to soil loss due to the mobilization of topsoil by the forces of water and wind. Wind and water move the eroded particles to some other location, where it is deposited as sediment. The critical aspect of soil erosion for our purposes here is that the rate of the process is highly dependent on human actions. Natural rates of soil erosion are lower for soil with a good cover of vegetation than for bare soil. In fact, any human actions that uncover soil (e.g., farming, logging, building, overgrazing, off-road vehicles, fires, etc.) enhance soil erosion rates;

- Chemical degradation (loss of nutrients, salinization, contamination and acidification).- Soil salinization is the concentration of salts in the surface or near surface of soils. Human induced salinization is often associated with large-scale irrigation. When drylands are irrigated, the water evaporates quickly, leaving behind previously dissolved salts. These salts can collect, since there is little rain to flush the system. The salt in the soil inhibits the uptake of water by plant roots and the soil can no longer sustain a vegetative cover. Nutrient loss occurs when essential nutrients are taken away in the crop and not replaced;
- Physical degradation.- Refers to the deformation of soil structure, by agricultural (heavy) machinery, surface sealing by traffic and settlement areas.

We may think that the objective of sustainable soil use is to combine the preservation or regeneration of the natural abiotic and biotic basis of landscapes with economic land use. In emphasizing the maximization of short-term profits, the farmer is destroying the capital upon which the business depends. Aside from economic considerations, the actions to stop soil degradation may go beyond a single actor. Soil conservation measures may be required on a regional or national level (water management or use of pesticides for example). It seems that the sustainable use of soil can only be solved through a variety of actions addressing a multitude of causes on various levels of aggregation ranging from the individual, the farm, the society as well as to the international community.

2.6.2 Irrigation

In many regions, irrigation is essential to grow crops that would not otherwise survive (Siebert et al. 2006). In areas where irrigation is necessary, a completely new set of problems is encountered, in particular, salinization, and water logging. All soils contain various mineral salts. Under natural conditions, arid regions tend to have high concentrations of salts in the soil and in any groundwater because there is not a constant flow of water to remove the salt. Irrigating arid land dissolves the salts in the soil, and as the water evaporates, the salts are drawn towards the surface. Many artificially irrigated lands are poorly drained, and as a result, the salts remain in the upper levels of the soil rather than being flushed out. Furthermore, the (poor drained land) can become water logged. As land becomes increasingly salinized, it may reach a point where it cannot any longer support plant growth (Francois and Masu, 1994).

2.6.3 Pesticides

Wherever agriculture has been practiced, pests have attacked, destroying part or even the entire crop (EPA, 2007). In modern usage, the term pest includes animals (mostly insects), fungi, plants, bacteria, and viruses. Human efforts to control pests have a long history. Even in Neolithic times (about 7000 BC), farmers practiced a crude form of biological pest control involving the more or less unconscious selection of seed from resistant plants. In his Natural History, the Roman author Pliny the Elder describes picking insects from plants by hand and spraying. The scientific study of pests was not undertaken until the 17th and 18th centuries. The first successful large-scale conquest of a pest by chemical means was the control of the vine powdery mildew in Europe in the 1840s. The disease, brought from the Americas, was controlled first by spraying with lime sulfur and, subsequently, by sulfur dusting (Encyclopedia Britannica 2011).

Another serious epidemic was the potato blight that caused famine in Ireland in 1845 and some subsequent years and severe losses in many other parts of Europe and the United States (Mazoyer et Roudart, 2006). Insects and fungi from Europe became serious pests in the United States, too. Among these were the European corn borer, the gypsy moth, and the chestnut blight, which practically annihilated that tree. The first book to deal with pests in a scientific way was John Curtis's Farm Insects, published in 1860. Though farmers were well aware that insects caused losses, Curtis was the first writer to call attention to their significant economic impact. Other pesticides that were developed soon thereafter included nicotine, pyrethrum, derris, quassia, and tar oils, first used, albeit unsuccessfully, in 1870 against the winter eggs of the

Phylloxera plant louse. The Bordeaux mixture fungicide (copper sulfate and lime), discovered accidentally in 1882, was used successfully against vine downy mildew; this compound is still employed to combat it and potato blight. Since many insecticides available in the 19th century were comparatively weak, other pest-control methods were used as well. A species of ladybird beetle, Rodolia cardinalis, was imported from Australia to California, where it controlled the cottony-cushion scale then threatening to destroy the citrus industry. A moth introduced into Australia destroyed the prickly pear, which had made millions of acres of pasture useless for grazing. In the 1880s, the European grapevine was saved from destruction by grape phylloxera through the simple expedient of grafting it onto certain resistant American rootstocks. This period of the late 19th and early 20th centuries was thus characterized by increasing awareness of the possibilities of avoiding losses from pests, by the rise of firms specializing in pesticide manufacture, and by development of better application machinery.

In 1942, the Swiss chemist Paul Hermann Müller discovered the insecticidal properties of dichlorodiphenyltrichloroethane, which became known as DDT. DDT was far more persistent and effective than any previously known insecticide. Originally, a mothproofing agent for clothes, it soon found use among the armies of World War II for killing body lice and fleas. It stopped a typhus epidemic threatening Naples (Miller, 2004). Müller's work led to discovery of other chlorinated insecticides. Regarding the fungicide field in the first half of the 20th century, dithiocarbamates, methylthiuram disulfides, and thaladimides were found to have special uses. It began to seem that almost any pest, disease, or weed problem could be mastered by suitable chemical treatment. Farmers foresaw a pest-free millennium. Crop losses were cut sharply; locust attack was reduced to a manageable problem; and the new chemicals, by killing carriers of human disease, saved the lives of millions of people.

Problems appeared in the early 1950s. In cotton crops, standard doses of DDT, parathion, and similar pesticides were found ineffective and had to be doubled or trebled. Resistant races of insects had developed. In addition, the powerful insecticides often destroyed natural predators and helpful parasites along with harmful insects. Insects and mites can reproduce at such a rapid rate that often when natural predators were destroyed by a pesticide treatment, a few pest survivors from the treatment, unchecked in breeding, soon produced worse outbreaks of pests than there had been before the treatment; sometimes the result was a population explosion to pest status of previously harmless insects. At about the same time, concern also began to be expressed about the presence of pesticide residues in food, humans, and wildlife. It was found that many birds and wild mammals retained considerable quantities of DDT in their bodies, having accumulated along their natural food chains (Carson, 1962; UNEP, 2008).

2.6.4 Industrial Production of Soil Nutrients

The main nutrients applied to the soil are nitrogen, phosphorous and potassium. In contrast to the natural process of soil fertility described in section 2.6.1; nowadays, the concept of fertility has an industrial orientation (McKenney, 2002). The possibility to produce ammonia (see section 2.3.4) together with mined phosphate and potash made possible to produce synthetically nutrients to grow crops. The availability of these nutrients –in large amounts- have the potential to create pollution, destroy natural habitats and contribute to high energy consumption. Every living organism on Earth needs nitrogen (Smil, 2002). Nitrogen is an essential part of amino acids and nucleic acids, and therefore of proteins and genes, in the cells of all living organisms, whether animal or vegetable. Plants get theirs from the soil. The soil gets its nitrogen from the excreta of soil fauna such as nematodes and protozoa, fixation by bacteria, biochemical watering of bedrock, rainfall and decaying bodies of all the soil's flora and fauna. Agricultural activities remove nutrients from the soil. In traditional (pre-industrial) agriculture, farmers had 3 ways in which to provide N for crops: 1) recycling of organic wastes (mainly crop residues and animal and human wastes); *2*) crop rotations including N-fixing leguminous species; *3*) and planting of leguminous cover crops (alfalfa, vetches, clovers) that were plowed under as green manures. The increase in food production that the development of the Haber-Bosch process facilitated has led to a very substantial increase of conventional agricultural practices. Smil (2001), estimates that "about half of the population of the late 1990s could be fed at the generally inadequate per capita level of 1900 diets without nitrogen fertilizer." Erisman et al. (2008) calculate that Nitrogen fertilizers feed 48% of the current world population. Of the total nitrogen manufactured by the Haber-Bosch process, approximately 80% is used in the production of agricultural fertilizers. What was not evident by 1900, however was the environmental (negative) effects, including the increase in water and air pollution, the perturbation of green houses-gas levels and the loss of biodiversity that was to result from the increase in ammonia production (Erisman et al., 2007).

Phosphorous in particular is potentially in short supply as high-grade naturally formed phosphate deposits are exploited faster than new deposits are discovered. Like fossil fuels there are only finite supply of geologically formed high-grade phosphate deposits (Cordell et al., 2009). The difference between energy and phosphorous is that there is not alternative for phosphorous, so solutions will have to come from either less demand, a more efficient use and reuse or less losses in the chain from mining to the dinner table (Abelson, 1999). Phosphorus has many important functions in plants (Sharpley 1996), the primary one being the storage and transfer of energy through the plant. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP) are high-energy phosphate compounds that control most processes in plants including photosynthesis, respiration, protein and nucleic acid synthesis, and nutrient transport through the plant's cells. Phosphorous is also essential for seed production; promotes increased root growth; promotes early plant maturity (less time for grain ripening); promotes stalk strength; promotes resistance to root rot diseases; promotes resistance to winter kill (Pierzynski, 1994). Although the benefits of P on agricultural production are evident, this element can be a pollutant if it moves from the site. The main concern is P transport from soils to streams, rivers, lakes, and eventually oceans. Phosphorus transported from agricultural soils can promote eutrophication, which is enrichment with nutrients that leads to increased algal growth, and decreased dissolved oxygen. Although no clear guidelines exist regarding the concentration of P in runoff considered eutrophic, recommendations have been made to critical P concentrations expected to cause noxious aquatic growth in downstream waters (Beauchemin, 1999).

2.6.5 Social Concerns

According to Van Der Ploeg (2008) industrialization of agriculture resulted in both commercialization of agricultural holdings increasingly embedded in the "treadmill" of production and profit maximization and the emergence of large agri-business often poorly rooted in local rural communities. The outcome has been regional specialization of agricultural production and the concentration of farming through the amalgamation of smaller farm units into more efficient larger holdings with associated declines in labor units. This has severe repercussions for the lengthening of agro-commodity chains, characterized by rapidly increasing in the distance that food has to travel to reach consumers and the dislocation of food from its local and regional provenance with associated loss of consumer knowledge about the provenance of their food. Besides, the industrialization process along with the strengthening of large and globally networked agri-business and the commercialization of agricultural production practices resulted in the rise in corporate involvement, which has increased opportunities for larger economically buoyant farm holdings while at the same time reducing opportunities for small and economically struggling farm family based units. Farmers were caught up in many cases in a dependency on large agro-chemical companies and agricultural institutes, which have dictated what farmers can grow and how they should go about their animals and crops from pests and diseases. Another social concern is the decline in agricultural labor due to the increased mechanization of farms (most former agricultural workers moved to urban areas to find employment).

2.6.6 Genetically Modified Organisms

The use of genetics to develop new strains of plants and animals has brought major changes in agriculture since the 1920s (National Research Council, 2004). Genetics as the science dealing with the principles of heredity and variation in plants and animals was established only at the beginning of the 20th century. Genetically modified (GM) organisms are plants that contain genes extracted from other types of organisms inserted artificially into the subject organism (Firbank and Forcella 2000). Humans have been selectively breeding and hence artificially modifying the genes from different plants but so-called genetically modified organisms are different. Traditionally breeding involves the crossing of organisms that are closely enough that they can interbreed (McKinney and Schoch, 2003). The engineering of transgenic organisms involves the mixing of genes from organisms that are widely separated evolutionary, such as the inserting of bacterial genes in a plant or animal, or even animal genes in a plant or vice versa. Direct desired benefits include increasing crop yields, developing more advantageous characteristics of crops, resistance to pests and tolerance to herbicides and pesticides. Genetic engineering can change the taste or other properties of plants by modifying their sugar and starch content. It contributes to increase the resistance of crops to insect and disease vectors. From a human dietary perspective, it can improve the nutritional content of food. Through transgenic engineering plants can also be developed that will yield precursors of plastics, vaccines and other products. GM crops such as those described above have incredible potential, to increase production and decrease costs, and thus transgenic crops have been adopted in a few countries, led by the USA.

Several authors have argued against GM crops (Bruinsma, 2003; Hogg, 2000; Ruttan 2002). In many European countries there is concern about genetically modified crops (Szirmai, 2005). The major concerns of those who oppose GM foods, center on the potential danger to the environment and the possible health risks to humans in the long term. The genetic structure of any living organism is complex and GM crop tests focus on short-term effects. Not all the effects of introducing a foreign gene into the intricate genetic structure of an organism are tested. Herbicides that are more noxious had to be used to remove the remainder of the plantation. A further complication is that the pesticide produced in the crop may unintentionally harm creatures. In Britain, a native farm bird, the skylark, was indirectly affected by the introduction of GM sugar beets designed to resist herbicides. In planting this crop, the weeds were reduced substantially. However, since the birds rely on the seeds of this weed in autumn and winter, researchers expect that up to 80% of the skylark population would have to find other means of finding food (Firbank and Forcella, 2000). GM crops may also pose a health risk to native animals that eat them. There have been laboratory studies indicating that pollen produced by GM corn can harm or kill monarch butterfly. Very little scientific information exists about the risk of GM food on human health. A report by Pusztai (2001), explains how GM foods could trigger new allergies and contain toxins that may be harmful. However, until further studies can show that GM foods and crops do not pose serious threats to human health or the world's ecosystems, the debate over their release will continue. Living organisms are complex and tampering with their genes may have unintended effects.

One controversy surrounding the GMO´s is their potentially damaging environmental effects. Social concerns have been raised as well. Some authors have observed that new technologies could favor (only or mostly) large farmers or multinational corporations to the detriment of smaller farmers (Nelson et al., 1999). One example of this is discussed by Mendelson (2002). Monsanto controls 60% of all utility soybean patents and 30% of all utility corn patents. If this trend continues farmers will lease their plants from conglomerates and pay royalties on seeds and offspring. Besides, if only large farmers are beneficiaries of GMO´s, what would small farmers do? One possible outcome is that small farmers are obliged to leave their enterprise and to emigrate to other activities, if any, in other sectors. Another issue is the shift of agricultural research away from the historic pattern of public research and public goods. GMOs can reorient agricultural research in ways that are unfavorable to the poor and marginal farmer in less developed countries (Comstock, 2000). GMO´s create a lasting dependence on the corporations that manufacture them. For example, if a specific GMO crop requires specific herbicides, that are manufactured by the same companies that engineer the crops (Barker, 2002).

2.7 Outlook after the Green Revolution

The past decades witnessed a change in agricultural practices largely due to the Green Revolution. While the revolution lead to production increases, it has also been criticized for its adverse human health and environmental impacts. Sustainability has emerged as an alternative to agricultural practices that address the many constrains faced by conventional agriculture. Sustainability, as we discuss in chapter three, centers on the need to incorporate agricultural technologies and practices that contribute to overall welfare by providing sufficient goods and services in ways that are economically profitable, socially responsible while also improving the environment. This is known, as the Triple Bottom Line approach (see chapter 1; Elkington, 1994). The Triple Bottom Line includes three elements in order to achieve sustainability: 1) economic, 2) environmental, and 3) social. Although the aforementioned elements are often discussed separately, they are mutually inclusive since sustainable agriculture aims at meeting social, environmental, and economic issues simultaneously. Hence, agriculture is based on farmer management decisions made in interaction with the biophysical, ecological, and social context. Knowledge about these contexts is complex. Knowledge includes both a set of concepts that happen to deal with the particular domain of agriculture and concepts that coexist with numerous other changes in the different domains.

Knowledge within the conventional agriculture model has been embodied in mental models of how science and technology “keep agriculture moving” (Mosher, 1966; Borlaug and Dowswell, 1995). This model gained credibility from the rapid and widespread adoption of the first products of the Green Revolution emerging from basic and strategic research (Jones, 1986; Evenson and Gollin, 2003). In the conventional agriculture model, science is positioned as a problem defining and knowledge generating activity carried out mainly by universities and research stations whose knowledge is transferred by extension agents to farmers. The underlying assumption is that farmers are passive cognitive agents whose own knowledge is to be replaced and improved as a result of receiving messages and technologies designed by others and communicated to them by experts (Röling, 1988; Blackburn, 1994; Röling and Wagemakers, 1998). Criticism of this model began to emerge in the 1980s as evidence of negative socioeconomic and environmental impacts of the green revolution. For example, farmers have been excluded or marginalized from farming policies. Preference has been given to short-term goals vs. longer-term agroecosystem sustainability. (Freebairn, 1995; Roling et al., 1976; Jiggins, 1986).

Some authors indicate that mental models of knowledge processes are needed to guide practice if broader development goals are to be reached (Hunter, 1970). The knowledge model given by the green revolution was shown to be unfit for organizing knowledge processes capable of affecting heterogeneous environments and farming populations (Hill, 1982). The assumption that a farmer is merely a passive receiver of information and technology was shown to be wrong since every individual engages in the full range of knowledge processes. The growing recognition of the complexity of knowledge processes and relations among a multiplicity of diverse actors has led us to pay attention to the role of farmers as information processors (Jorna, 2006; Faber, 2006). In chapter four we explain in detail that, according to the HIP hypothesis of Newell and Simon (1972), farmers are considered as knowledge and information processing systems. Based on this cognitive approach, three elements related to cognition are distinguished: a cognitive architecture, mental representations, and operations based on these mental representations (Faber, 2006; Jorna, 2006). A cognitive architecture is referred to as the structure of cognitive functions such as memory, processing capacity and perception (Wilson and Keil, 1999). Mental representations refer to the knowledge that exists in the memory of persons in the form of representations that can be retrieved. The operations based on the mental representations occur when they are used, altered, combined, and or complemented.

Farmers behave as information processing systems that are continuously interacting and making sense of events occurring within the agricultural system. From the perspective of systems dynamics, knowledge creation and knowledge artifacts are essential. Simon (1969) makes a distinction between natural and artificial. Artificial refers to human-made as opposed to natural. For Simon, our world is much more an artificial, that is, a human-made, than a natural world. The human-made world refers to artifacts. He distinguishes two kinds of artifacts: physical and the immaterial. Examples of physical artifacts are machinery and buildings. Examples of the immaterial world are policies, organizations and knowledge that people have. In this research, we do not deal with the natural objects and physical artifacts. Instead, we focus on non-material artifacts. In this case, the knowledge individuals -that constitute the system- have. Thus, we consider the agricultural system as a non-material artifact; Farmers are the essential actors in these artifacts. Apart from the machinery and other materials, an agricultural system exists by virtue of the fact that farmers have mental representations of the agricultural system. They are the most important actors within the agricultural system and give it a reason to exist by thinking and acting about it.

In summary, we state that the agricultural system have multiple outputs and contributes to several ends at the same time. Agricultural development has started with the assumption that there is knowledge that "works," and so it is just a matter of inducing or persuading farmers to adopt it (Leewis and Van den Ban, 2004). This has not been the case (Kerr and Kolavalli, 1999). We propose a knowledge approach towards agriculture. This approach centers on the farmers as the main actors within the agricultural system and in understanding the knowledge structures farmers have and use while performing agricultural tasks. This new approach ranges from passive participation, where farmers are told what is to happen and act on predetermined roles, to active participation where farmers take decisions based on the understanding of the knowledge structures they possess. This knowledge approach can promote changes in behavior bringing sustainable practices within agriculture.

3 SUSTAINABILITY

3.1 Introduction

In chapter two we stated that agricultural systems face growing concerns about meeting farmer needs with preserving the life systems of planet earth. Regarding the Netherlands it is expected that the agricultural sector produces sufficient and healthy food at acceptable prices within a rural area that is used for leisure and values nature (Ministry of Agriculture Nature and Food Quality of the Netherlands, 2008). The 4th National Environmental Policy Plan for the Netherlands (VROM, 2001) concluded that there is a need for a transformation process towards sustainable agriculture. In our research, we explicitly aim at a situational rather than at a generic definition of sustainability. This means that once we have studied agriculture in chapter two, now we will study sustainability within agriculture. The structure of the present chapter is as follows. We will give an overview of the different meanings of sustainability. In second place, we will argue that in pursuing sustainability a multidisciplinary approach is needed. After this, we state that systems theory can help to handle the complexity that the multidisciplinary approach has. In the remaining sections we explain and describe how this shapes our understanding of sustainable agriculture. We will use this understanding in chapter five and six in obtaining an operationalization of sustainable agriculture.

3.2 The Meanings of Sustainability

The concept of sustainable development is an attempt to bridge the gap between environmental concerns and socio-political concerns about human development issues. (Munasinghe, 2001, CIEC, 2008). When the World Commission on Environment and Development (WCED) published their results on "Our Common Future," one of the main themes was sustainable development. The definition of sustainable development adopted by WCED is nowadays the most widely adopted: "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Lafferty and Eckerberg, 1998, UN 2007). The 1992 Earth Summit in Rio de Janeiro accelerated the process of debating over sustainability. It has since been co-opted by many discourses to mean various and sometimes-incompatible things. Many different expressions have been used and there is still debate about what sustainability means (Faber, 2006; McElroy, 2009; Jorna, 2006). Wals and Jickling (2002) list, below, eleven understandings of sustainability. They offer a useful summary to understand the different emphases that sustainability has influenced.

1) Sustainability as (socially constructed) reality (to be taken seriously).

The terms sustainable development and sustainability have been used to characterize the future to which humanity should aspire. Like other fashionable words and phrases, these can be misunderstood and misused. At a rather simplistic level, the concept is easy enough to understand and it would seem to have widespread and powerful support. Applying the concept makes things more complex. Understanding sustainability – in the field of agriculture- as a complex concept that can provide a basis for approaching its expected ecological and socioeconomic impacts now and in the future is itself of considerable value.

2) Sustainability as ideology and therefore political.

If we want to understand the politics of the environment and the attitudes of various people and groups toward questions of material progress and sustainability, we have to understand ideology as a social and political force. It is argued that sustainability has provided a quilting point that has enabled new social and urban policy-related partnerships and organizational agendas to be developed (Davidson, 2010). However, this coherence remains unstable because efforts at definition and agreement may be dominated by the non-presence of sustainability (Lotz-Sisitka, 2004).

3) Sustainability as negotiated, the result of (on-going) negotiations.

Participation has become a widely advocated principle in discussions around rural development (Leeuwis, 2000). Negotiation theory –and practice- can bring insights to the current sustainability debate. The concept of sustainability differs over time and can be discussed at different levels of aggregation. Therefore, the study of sustainability within agriculture should include different actors with different backgrounds but specially it should bring the knowledge of farmers into the debate.

4) Sustainability as contextual, its meaning is dependent on the situation in which it is used.

Context can be understood as the circumstances, conditions, factors and patterns that give meaning to a particular system (Souza-Poza et al. 2008). Within the path towards sustainability every situation, technology, and process is different and demands a unique response.

5) Sustainability as a vision to work towards.

Sustainability is a process, a dynamic one (Jorna, 2006). This process has a constantly moving target whose boundary evolves as the agricultural system evolves. Knowing about sustainability presupposes that those who transmit the knowledge consider themselves as knowledge apprentices as well and that receivers have knowledge too. It incorporates debates about norms and values and directly relates to the destination of humankind and human responsibility.

6) Sustainability as a dynamic and/or evolving concept.

Sustainability concerns both human and natural systems. These systems are always evolving (Dale, 2001). Therefore, the concepts that aim at describing both systems will also evolve. Wals and Jickling (2002) note that when Carson wrote Silent Spring, no one heard of deep ecology. When Naess coined the term deep ecology in 1972, nobody had heard of the term sustainable development. In other words, we have no idea of how (our) knowledge and understanding of such a complex issue will develop.

7) Sustainability as controversial and the source of conflict (both internal and with others)

Sustainability seems sometimes to claim a monopoly of belief: as a "belief," it cannot admit an opposite belief is equally valid. It is a consistent and universalist world-view. Some of its adherents act in accordance with one general principle: that all persons should accept it. The surrounding debates can be seen as healthy and positive because such a dispute is a driver to learn about a highly relevant, controversial, emotionally charged, and debatable topic at the crossroads of agricultural science, technology, and society.

8) Sustainability as normative, ethical, and moral.

Sustainability has been criticized as overly value-based. Jickling (2005) states that sustainability put as a desired outcome is a reminiscent of indoctrination. Sustainability has been used to misinform to gain advantage for narrow and special interests (Trzyna, 1995). We concur with Dale and Newmann (2005) on the validity of questioning a set of (sustainable) values as the basis of any policy. However, the transdisciplinary nature of sustainability allows reaching consensus among varying value systems.

9) Sustainability as innovation or a catalyst for change.

Innovation can be seen as a process of knowledge development. Jorna (2006) identifies two phases within innovation: conceptualization and commercialization. Conceptualization refers to generation of new ideas (new knowledge). Commercialization denotes the transformation of these ideas into products or services. Sustainability can be also seen as a –learning- process (Faber, 2006), requiring in –depth knowledge of the current state of affairs within the agricultural domain but also demanding humans to –constantly- develop new knowledge. McElroy (2003) argues that learning and development of new knowledge is a basic natural process in human actors (farmers in the case of this research).

10) Sustainability as a heuristic, a tool-to-aid thinking.

The sustainable approach provides a framework to help understand the main factors that affect man's livelihoods, and the relationships between these factors. This in turn facilitates the planning and implementation of more effective development interventions. By centering thinking around people rather than the technical inputs, development might deliver to them the chances of achieving sustainable impacts on farming.

11) Sustainability as a (temporary) stepping-stone in the evolution of environmental education and of environmental thought

The vagueness of the definition and the multiple definitions of the sustainability concept (Jorna, 2006) has led some authors to argue that sustainability in education is not a meaningful undertaking (Foster 2001; Gough, 2002). However, this can be taken as an opportunity for higher education institutions to grapple with it and develop new ways of thinking about the concept. Universities should provide the opportunity to create possibilities, to confront values and way of thinking. Universities should not be used to implant a deterministic view and decide what is best for the society (Jickling, 2005).

We have reviewed several meanings of sustainability. There is not even one way of viewing sustainability. As it has been illustrated in the previous overview, various understandings can be united under the umbrella of sustainability such as an ideology, a negotiation, a vision, a norm, an innovation or as an heuristic. This variety shows that an unequivocal interpretation of what sustainability should be does not exist. We observe that in general, the aforementioned overview do not recognize knowledge as an explicit factor, although it encompasses understandings (or mental models) of sustainability. In this study, we situate the study of sustainability within the agricultural system. We aim at making the concept of sustainable agriculture operational. The basic assumption (see chapter 4) is that farmers within the agricultural system act as information processing systems. Knowledge is a resource that underlines the actions and behaviors of farmers in order to think and to make sense of sustainability. Hence knowledge plays a role in guiding farming actions. Therefore, it also plays a role in adopting sustainable practices. It is unlikely that farmers share the same mental model of sustainable agriculture. We believe that it is important to be familiar with these various models. First, without this knowledge a discussion about sustainability, including the question of how to make it operational, is likely to become unclear. Second, as a consequence of the aforementioned, an assessment of agricultural practices in terms of sustainability can hardly be made. Third, if the knowledge about existing models of (sustainable) agriculture is available, it can be shared throughout the several stakeholders

In the context of agriculture, sustainability seeks to make the best use of the inputs the agricultural system has, generating the less negative impacts as possible. We can outline some implications of integrating sustainability into agriculture. What makes agriculture unique is that it directly affects the vary subsystems of which it is composed. Thus, sustainable agricultural systems tend to have a positive effect on the subsystems, whilst unsustainable ones deplete these subsystems over time (leaving fewer assets for future generations). This suggests that a key approach towards sustainability is the view that it should not be conceived of as a single concept, or even a consistent set of practices. There are likely many ways towards sustainable agriculture. When recognizing that sustainability is an unclear concept that derives meaning in a specific context with the involvement of multiple stakeholders, a question is raised as how to cope with the issues that arise in working with sustainability. This leads to the role of disciplinarity in exploring sustainability. We believe that acknowledging contributions and interests of many disciplines can direct solutions to the challenges that the agricultural system faces.

3.2.1 Disciplinary Approaches within Sustainability

One of the major outcomes of the appearance of the sustainability concept witnessed over the past three decades was its effect on various disciplines of science. During the post war period the approach to solve problems was the period of disciplinary response during which each scientific discipline made an attempt to understand the causes of the environmental crises from their own disciplinary domain. The multidisciplinary responses are based on an extension of the basic principles and theories of the disciplinary domain toward the field of environment, which is inherently an area of dynamic complexity. The (mono and multi) disciplinary exercises have been important (Mebratu, 1998) because: 1) they have significantly expanded the knowledge base about the different aspects of the environmental crisis and 2) it has opened up a research agenda for the sciences that extends well beyond the traditional environmental issues. Nevertheless, none of the disciplines that aim at tackling the environmental crisis, as a stand-alone approach, can describe the nature of the environmental crisis and its solution. The independent solutions generated and proposed within the multidisciplinary domain have a limited scope of application and influence in dealing with the complexity of the environmental crises. Thus, despite the significant progress made in the field of environmental economics and environmental engineering during the last three decades, they have registered a limited success in terms of transforming societies into more sustainable production and consumption patterns. We should not neglect the importance of the traditional (disciplinary or reductionist) approach since we owe the technological development to it. The complexity that sustainability poses cannot be tackled with this approach. Real life issues hardly ever match traditional monodisciplinary approaches in applied scientific research. Sustainability issues are one of the complex and dynamic subjects that essentially fall beyond the reach of a disciplinary scientific approach.

With the emergency of the concept of sustainability, there is an increased need for interdisciplinary research (Schoot Uiterkamp and Vlek; 2006). Multidisciplinary means that a particular problem is studied from different scientific approaches. To the extent that this consideration succeeds, it evolves towards interdisciplinarity. That is when different approaches are merged together and neatly integrated. Practicing interdisciplinarity is challenging. Scientists of a particular discipline may thus understand the limitations and shortcomings of their own approach and in conjunction they may learn to understand and to appreciate each other's perspectives. The interdisciplinary response is the current dominant approach to environmental issues. One example of such approaches is the "Triple Bottom Line or 3P" (people, planet and profit) concept coined by Elkington (1994). Although sustainability may have one of many definitions and there is a lack of consistency in its definition (Eden 1994; Jorna 2006), it appears that the different definitions discussed in the literature comprise (to a different extent) the concept of three basic elements: the ecological, economic, and the social (Figure 3.1).

- The ecological element. That is, to stay within the biophysical carrying capacity of the planet;
- The economic element. That is, to provide an adequate material standard of living for all;
- The social element. That is, to provide governance, social cohesion and livability that propagate the values that people want to live by.

Thus, 3P might be a good starting point for the sustainability framework of this research. Lele (1991) notes that these three categories are only conceptual devices for clarifying human thinking; real "sustainability" issues seldom fall in one specific category. These issues are a complex combination of the three P´s.

The 3P acknowledges that the social and economic dimensions of the agenda should have to be addressed in a more integrated way if real environmental progress was to be made. Not only has the 3P become the dominant approach to public sector accounting and a mainstay in private sector firms demonstrating their virtue as a sustainable organization (Robbins, 2006; Savitz and Weber, 2006), but the concept has been widely diffused and adopted by the public and by scholars. Because businesses (small and big, private and state owned) contribute to the impact over the environment, 3P uses a language that resonates with business brains. The accepted understanding of the 3P is based on the recognition of the supposedly separate existence of the natural, economic, and social systems. As a result, the model is predominantly used in many articles as the basis for describing the sustainable development process (Vandenberg, 2002; Gray and Milne, 2003; Vanclay, 2004; Quinn and Baltes, 2007). This model suggests that the natural, economic, and social systems are independent systems and may be treated independently.

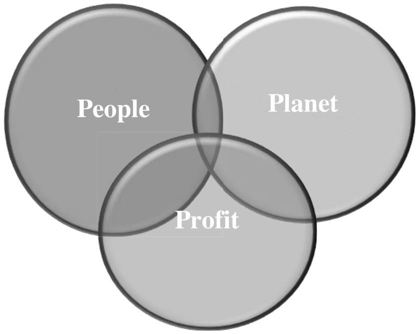


Figure 3.1 The Triple Bottom Line

However, some authors argue that this view responds to and perpetuates a business as usual (Raskin et al., 2002). This has led to what Chapman (2004) calls techno centric environmentalism where notions of sustainability developed from these values base cannot contribute to long-term solutions. Therefore, the original model illustrated by Elkington has been transformed in what some authors call the dominant Pig-headed model (Figure 3.2). In this model, the economy is the main circle, while society and environment are two minor, subsidiary circles with minimal influence. The underlying assumption is that any problems encountered in society and environment will be solved by economic means. We believe that within certain economic and politic circles the economy is seen as “the system”, within which environment and society can be subsumed as subsystems. However, the economy, as a human construct, is a subsystem of society. Society in turn, is a subsystem of the biosphere.

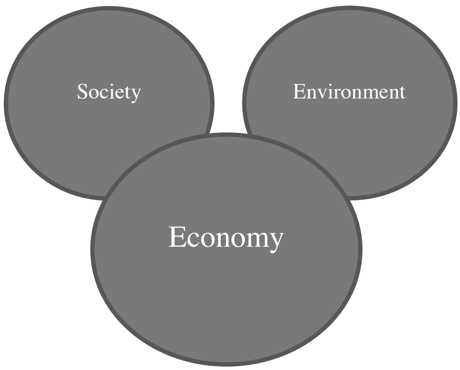


Figure 3.2 Pig Headed Model

As a complement to multi and interdisciplinary approach, transdisciplinarity signifies the crossing of boundaries between scientific and non-scientific communities. Transdisciplinarity represents a set of interactions between the scientists and representatives of industry, government, or civil society. This may deepen society's understanding (as a whole) of complex problems –such as sustainability- and may prevent the selection of too limited or biased solutions. Scientists have suggested that a more appropriate ethic is "interconnectedness," based on responsibility for "the well-being of others, nature and future generations" (Raskin et al., 2002). Support in this sense implies that institutions understand the need to change and make a commitment to a changed paradigm along the lines suggested above. This is radical because it challenges the current discourse of industrial society. It "calls for imagining new grounds whilst destabilizing old forms" (Heath, 2000; Sterling, 2003).The challenge that poses the building of a sustainable world is social in nature. It arises out of the interaction of human beings with each other, with the environment and with the economy. It is a challenge of interdependency. In spite of the technical ability and technical brilliance that have been directed towards eradicating the problems under the shadow of the sustainability definition, reality is that our world is still unsustainable. No one deliberately creates those problems, none wants them to persist, but they persist nonetheless. That is because it is intrinsically a systems challenge; a challenge of system configuration.

3.3 Systems Theory

The need for general systems theory has received attention due to the difficulty of talk among scientists from different disciplines (Boulding, 1956). Specialization has become the norm and communication between disciplines becomes increasingly difficult. Hence, physicists only talk to physicists, economists only talk to economists, and environmentalists only talk to environmentalists. The more science breaks into sub-groups the less communication is possible among the disciplines (since each of them uses words in a private language that only they can understand) but the greater chance there is that total growth of knowledge is slowing down by the loss of relevant communication (von Bertalanffy, 1951). Systems Theory and systems thinking provide a framework to talk about and represent complexity and change (Chen and Stroup, 1993; Martin, 2002). Jay Forrester, makes a clear distinction 'Systems thinking' has no clear definition or usage […] Systems thinking is coming to mean little more than thinking about systems, talking about systems, and acknowledging that systems are important. In other words, systems thinking implies a rather general and superficial awareness of systems." (Forrester, 1994). He accepts systems thinking as a door opener for system modeling but opposes the idea of equality of system theory and systems thinking. However, some scholars do not apply the distinction. Ossimitz (2000) uses the two concepts side-by-side when referring to his own empirical studies. He presents the ability to think in interrelated, systemic structures and thinking in dynamic processes (for example delays and oscillations) as two of the essential dimensions of the compound subject system dynamics/systems thinking. The view taken in this study is in line with Ossimitz (ibid.) and with Coyle (1996), who does not want to make the distinction either, but holds that system theory can be used as an aid to thinking about and understanding how a system works. Several authors discuss how Systems Theory has been elaborated and used (von Bertalanffy, 1969; Ackoff, 1971; Laszlo, 1972; Checkland, 1981; Sengue, 1990; Richmond, 2005; Jorna 2006; Meadows, 2008).

Systems thinking focuses on how parts of the system under study interact with each other within the system. This means that instead of isolating smaller parts of the system being studied, systems thinking works by expanding its view to take into account larger numbers of interaction. As an example that illustrates the difference between the systems thinking perspective and the conventional perspective in agriculture we can look at the action to reduce crop damage by insects. When an insect is attacking a crop, the conventional response is to spray the crop with a pesticide to kill that insect. The outcome here is that as the amount of pesticide applied increases, the number of insects damaging crops decreases. According to this approach, the greater the pesticide application, the smaller the numbers of insect A (the original pest) that will eat crop. This leads to a decrease in the numbers of insects eating the crop (the intended effect of pesticide use). However, the smaller the numbers of insect A eventually lead to greater numbers of insect B, because insect A is no longer controlling the numbers of insect B to the same extent. This leads to a population explosion of insect B, to greater numbers of insect B damaging the crop. Thus, although the short-term effects of applying the pesticide might be what it was intended, the long terms are different. Besides, conventional methods to control insects might have also other negative effects such as water and soil pollution and the health risks posed to the farmers that work with them. Other actions, based on a systems thinking approach, have been developed such as integrated pest management (IPM), which seeks to reduce the use of chemical agents by introducing more of its natural predators into the area and by breeding pest-resistant crops (Tripp, 2006).

3.3.1 Systems Characteristics

Systems theory and systems thinking provide a framework to talk about and represent complexity and change. The framework is used to solve a problem or to reach a goal by constructing models that are governed by a methodological structure. While many scientific methods recommend studying the world by breaking it up into smaller and smaller pieces, system theory emphasizes looking at things as a whole. A system is seen as a complex whole of which the functioning depends on its parts and the interactions between those parts (Jackson, 2003). Systems can be defined at different levels of aggregation. Boulding (1956) explains how systems are organized in hierarchies. The first level is called the level of frameworks. This is the basic structure upon which the accurate description of these frameworks lies. It is the beginning of organized theoretical knowledge in almost any field. The second level of systematic analysis is that of the simple dynamic system with predetermined, necessary motions. This might be called the level of clockworks. Two special cases might be noted. Simple equilibrium systems and stochastic dynamic systems leading to equilibria. The level of the "clockwork" is the level of classical natural science, especially physics and astronomy, and is probably the most completely developed level in the present state of knowledge. Beyond the second level, adequate and total (complete) theoretical models get scarcer.

The third level is that of the control mechanism or cybernetic system, which might be nicknamed the level of the thermostat. This differs from the simple stable equilibrium system mainly in the fact that the transmission and interpretation of information is an essential part of the system. The theory of control has established itself as the discipline of studying these systems. The fourth level is that of the "open system," or self-maintaining structure. This is the level at which life begins to differentiate itself from none-life: it might be called the level of the cell. As the scale of complexity of an organization towards living systems is passed up, the property of self-maintenance of the structure in the midst of a throughput of material becomes of dominant importance. The fifth level might be called the genetic-societal level; it is typified by the plant. The characteristics of these systems are first, a division of labor among cells to form a cell-society with differentiated and mutually dependent parts. At this level there are no highly specialized sense organs and information receptors are diffuse and incapable of much throughput of information. The sixth level is the "human" level, which is of the individual human being considered as a system. Man possesses self-consciousness, which is something different from mere awareness. This property gives the capacity for speech; the ability to produce, absorb, and interpret symbols.

The seventh level is that of social organizations. The unit of such systems is not perhaps the person-the individual human as such-but the role that part of the person, which is concerned with the organization or situation in question. In order to complete, the structure of systems final turret for transcendental systems is added. The eight level, transcendent level, corresponds to the ultimates and absolutes and the inescapable unknowable, and they also exhibit systematic structure and relationship. One of the uses of the hierarchical description is to prevent researchers from accepting as final a level of theoretical analysis that is below the level of the empirical world, which we are investigating. Because, in a sense, each level incorporates all those below it, much valuable information and insights can be obtained by applying low-level systems to high-level subject matter. Most of the theoretical schemes sustainable agriculture studies are still at the first and second levels. For example, knowledge over the soil quality has been developed as well as for different products used to grow crops (fertilizers, herbicides, etc.). Although the subject matter clearly involves the eight level of hierarchy since there are different interactions among the different parts of the system.

The central concept of systems theory is to understand how parts in a system interact and to seek underlying systemic interrelationships that are responsible for the patterns of behavior, be it an ecosystem, a bank account, or a football team. A systems or systemic approach is well suited to identifying decisive information to support sustainable development for a number of reasons. Systems approach focuses on studying things in terms of their connection, context, and relationship as a whole (Kelly, 1998). Nature does not show us isolated building blocks but rather a complex web of relationships between the parts of a unified whole. The importance of each component of a system is tied to its relationship to the whole. Systems' thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static "snapshots." According to Senge (1990), 'it is a set of general principles distilled over the course of the twentieth century, spanning fields as diverse as the physical and social sciences, engineering, and management. Systems are integrated wholes whose properties cannot be reduced to those of smaller parts. Their "systemic" properties are properties of the whole that are possessed by none of the parts. In the systems view, the objects of study are networks of relationships. Shifting focus from the parts to the whole implies shifting from analytical thinking to contextual thinking. Explaining things in terms of their contexts means explaining them in terms of their environments. When a map of relationships is drawn, we discover that certain configurations of relationships appear repeatedly. Those configurations are called patterns (Meadows, 2008). Instead of (only) focusing on what a system is made of, it is relevant to study the patterns. This shift leads to discovering that understanding how a pattern works in one system helps to understand other systems that manifest the same pattern.

Systems are always (a) themselves composed of other 'lower order' systems (usually called sub-systems) and (b) are themselves sub-systems of 'higher order' systems (usually called supra-systems). Meadows (ibid.) noted an important concept within systems theory, the understanding of feedback. Feedback shows how actions can reinforce or counteract (balance) each other. Systems thinking build the ability to learn to recognize types of structures that recur repeatedly. Eventually, it forms a rich language for describing a vast array of interrelationships and patterns of change. Ultimately, it simplifies life by helping us to see deeper patterns lying behind the events and details (Senge, 1990).

3.4 Systemic Perspective for Sustainability

Based on the systemic view and (still) using the concepts derived from the Triple Bottom Line approach, figure 3.3 shows the *View from Space* proposed by Lowe (2005). It changes the perspective by highlighting a paradigm in which the economy is innermost, existing as a wholly-owned subsidiary of the second concentric ring, "Society", which itself is contained within the Earth's natural eco-systems, the outer ring, "Ecology". This view repositions economy so that it is no longer the main driver, to the detriment of all other elements, or at worst, a black hole into which all resources vanish. It assumes the position as one important sub-set within the ecology upon which all life depends (Kelly, 2006; Jorna 2010). Mebratu (1996) discusses a similar model called cosmic interdependence. He concludes that the human universe, in general, and the economic and social cosmos, in particular, never have been and never will be, separate and independent from the natural universe.

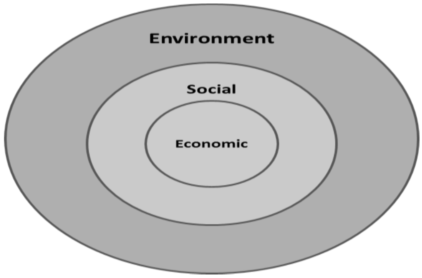


Figure 3.3 View from space perspective

The central idea here is that the agricultural system is formed of three main systems. These systems are whole entities with properties that are different from those of the sums of their (interconnected) parts. Thus, what is usually referred to, as the environment of a system is itself a system with systemic organization and properties. Systems are thus best thought of in three dimensions as a three level system of systems in which there are always complex networks of dynamic, ever-changing interconnections both within each system level, and between them, with unique properties emerging with each change of level. For the purposes of agriculture, we are going to adopt a special interpretation of the model drawn by Lowe model, where:

- The (farm) system is the network where only farmers operate
- The suprasystem is the agricultural environment in which farmer's supply chain has to operate, and
- The key subsystem is the farmer
-

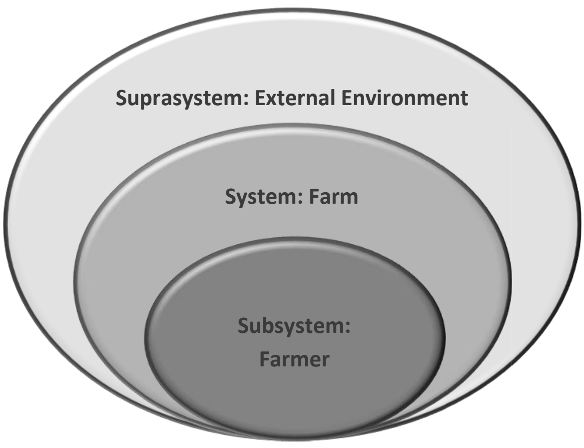


Fig. 3.4 Farm system components

We say that we are being systemic whenever we adopt this three dimensional view of looking at and dealing with a farm as if it were a system -in which farmer(s) are embedded- and which itself is embedded within its environmental suprasystem (figure 3.4).

3.5 Systemic Perspective in Agriculture

Agriculture is a complex system that relies on the physical environment and biota. Its success or failure can influence food security or famine and poverty. It is one of the key sectors to prevent environmental damage projected to 2030 because agriculture is the largest user of water worldwide and it is responsible for much of its pollution (OECD, 2008). According to the FAO, securing world food supply in light of the impact of climate change may be one of the biggest challenges humanity faces in this century. It is clear that in order to achieve sustainable development a continuous study on agriculture is needed. No one can define ultimately the concept of sustainability. The same applies to the concept of sustainable agriculture. F-or some authors (Raskin et al. 2002) the desirability of economic growth and socioeconomic development is undisputed. Herman Daly (2004) calls this “Growthmania.” Growthmania is the paradigm or mindset that always puts growth in the first place, the attitude that there is no such thing as enough that cannot conceive of too much of a good thing. We concur with this last vision. We argue that agricultural development should not be viewed in terms of economics only. One should also pay attention to changes in family structure, attitudes, and mentalities, cultural changes demographic development, political changes and the transformation of rural societies. Although there is no basic definition of development and there may be basic differences of opinion about its goals, the use of the concept is insightful to set a direction (Szirmai, 2005). However, the formulations vary greatly in practice. Most definitions about sustainable development come with a variety of goals: poverty reduction, increase of economic welfare, health and education improvements, political and social freedom, and preservation of the environment; development can be thought as a movement in the direction of these goals (European Commission, 1997).

The world conferences and summits since 1990 have been the best attempt in the history of the United Nations (UN) to give concrete content to integrate economic, social, and environmental policies. The world conferences have recognized the diversity of high priority goals to achieve sustainable development (UN 2007). Agriculture as an economic sector has been a major focus on the UN world conferences. It is noted that agriculture has a special and important place in society and helps to sustain rural life and land. Public opinion is aware of the problems caused by agriculture. The use of chemical fertilizers and pesticides threaten the quality of ecosystems. Consumers have higher demands on the quality of food and they are concerned with the way food is produced. Agriculture and its relationship between food security and high food prices are also discussed in international politics and business publications (The Economist, 2008).

According to the Agricultural Outlook 2008 from the Organization for Economic Co-operation and Development (OECD) and the UN Food and Agriculture Organization (2000) below are some of the expected trends for the coming years in the agricultural sector:

- Both consumption and production is growing faster in developing countries for all agricultural commodities except wheat. By 2017, these countries are expected to dominate trade in most farm products;
- High prices will be beneficial for many commercial farmers in both developed and developing countries. However, many farmers in developing countries are not linked to markets and are unlikely to benefit from the higher prices that are forecasted;
- Cereal markets are expected to remain tight, as stocks are unlikely to return to the high levels of the past decade;
- Consumption of vegetable oils, both from oil seed crops and from palm, will grow faster than for other crops over the next 10 years. The rise is being driven both by demand for food and for biofuels.

Brklacih et al. (1991) suggest six major factors that may cover the concept of sustainable food production.

- Environmental Accounting. - Identifying types of degradation or pollution on and off farm;
- Sustained Yield. - The sustainable output per unit area;
- Carrying Capacity.- Maximum population size that the environment can support;
- Production Viability. Long-term viability of agricultural production units. It measures how resilient to stress farm units are;
- Product Supply and Security. Access to Food;
- Equity. - Equitable distribution of food and intergenerational security, which can only derive from food security.

The concepts expressed above can be used as guidelines to promote sustainable agriculture but without any measurable element, they are only good wishes. Indicators have been seen as the core element in operationalizing sustainability. The advantage of the indicators is that we have a high degree of certainty in their calculation but sometimes their meaning is low. On the other hand, the developmental goals are small in number but high in meaning. Indicators can play a very useful role but only in terms of empowerment and not as precise measures. The fact that there is development a goal does not mean that all societies ought to develop in the same manner or that they ought to converge in the same standard. Local communities should own and develop their own view of sustainability via these developmental goals (Bell and Morse, 2008). Since the 1992 Earth Summit in Rio, it is generally accepted that the agriculture and environment agendas are inseparable. Degradation of natural resources undermines the basis for agricultural production and increases vulnerability to risk, imposing high economic losses from unsustainable use of natural resources. The agriculture for development agenda will not succeed without more sustainable use of natural resources—water, forests, soil conservation, genetically diverse crops and animal varieties, and other ecosystem services. At the same time, agriculture is often the main entry point for interventions aimed at environmental protection. It is the main user of land and water, a major source of greenhouse gas emissions, and the main cause of conversion of natural ecosystems and loss of biodiversity. The intricate links between the agriculture and environment agendas require an integrated policy approach. The large environmental footprint of agriculture on natural resources remains pervasive, but there are many opportunities for reducing it. The variety of meanings acquired by sustainability as applied to agriculture is also vast. Douglass (1984) and Weil (1990) have classified it according to four issues.

1) Sustainable Agriculture as an ideology

Sustainable agriculture is a philosophy and system of farming. It has its roots in a set of values that reflect a state of empowerment, of awareness of ecological and social realities, and of the farmer's ability to take effective action.' (MacRae et al., 1990)

2) Sustainable Agriculture as a set of strategies

It can be understood as a management strategy, which helps the producers to choose from a variety of techniques and tools in order to reduce costs and to minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming. (Francis et al., 1987)

3) Sustainable Agriculture as the ability to continue

According to Hamblin (1992), agriculture is sustainable when it remains the dominant land use over time and the resource base can continually support production at levels needed for profitability or survival.

4) Sustainability as the ability to fuel a set of goals

Agricultural systems that are environmentally sound, profitable, and productive and that maintain the social fabric of the rural community (Keeney, 1989).

Managing for a triple bottom line, as understood by the View from Space discussed in section 3.4 suggests managing for balance among the economic, environmental, and social dimensions of business performance, rather than maximizing profits or growth. Triple bottom line recognizes from a "Planet" perspective, arable farming is based on plant growth and on how different conditions as soil fertility, climate, and pests affect it. The focus is on how various management practices and environmental conditions affect yield and how these conditions can be improved.

Focusing on this aspect of sustainable agriculture leads to maintaining or improving current levels of biophysical productivity. From a “Profit” perspective, agriculture is an enterprise at the farm level and an important economic sector at the international, regional, national, and local levels. The focus on massive production was the main driver of the so-called green revolution, also known as the industrialized or conventional model of agriculture. The downside of conventional agriculture is that massive application of modern agricultural techniques has resulted in numerous ecological disadvantages such as mismanagement of resources leading to land degradation, impoverishment of the rural masses and the fact that farmers depend on a few multinationals. From a “People” perspective, agriculture is viewed as a producer with focus on its ability to satisfy requirements for food and fiber. Here, sustainable agriculture is associated with the prospects of meeting national and global food needs, quality and security of food supply, labor conditions, learning, well being of people and human development in a general sense. Human development comprises the process of enlarging people’s choices at three essential capabilities: to lead a long and healthy life, to be knowledgeable and to have a decent standard of living (McKinney and Schoch 2003; Szirmai 2005).

We have discussed different expert meanings on sustainability. Our conception of sustainability is synthesized in table 3.1. This synthesized version is not a definitive conception. However, it gives some indication of the breadth and depth of content and processes that we need to contend with in the field of (sustainable) agriculture. Furthermore, this is the sustainability conception that formed the foundation for construction of our approach in the study under discussion.

Table 3.1 Characteristics of sustainable agriculture

Positive Aspects	Challenges
Aims at equilibrium among the basic ecological cycles and natural balances diminishing pollution.	Lack of a concise definition
Ensures that the basic nutritional requirements of present and future generations, qualitatively and quantitatively, are met while providing a number of other agricultural products.	Operationalisation is sometimes difficult, especially concerning the social aspect.
Provides long-lasting employment, sufficient income, and decent living and working conditions for all those engaged in agricultural production.	Time consuming in reaching consensus among the different actors.
Maintains and enhances the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources,	Requires a new approach in thinking
Strengthens self-reliance of the farmers.	Requires the ability to exchange ideas and cooperate towards a common goal.

We would like to stress that our study considers farmers as processors of information (see chapter 4). Therefore, farmers are considered carriers of knowledge. They use this knowledge in order to perform actions within the agricultural system. When we talk about sustainable agriculture what we mean is that farmers perform sustainable (or unsustainable) agricultural actions or practices. As we described in chapter 2, agricultural systems rely on the services flowing from the total stock of subsystems that they influence. The notion of services flowing is also applied by McElroy in his definition of capital (McElroy, 2008). He also discusses the relation between action and the impacts that human activity can have on different capitals. Hence, we can say that agriculture relies on different types of capital. McElroy (ibid.) recognizes natural and anthro capital. Natural capital produces environmental goods and services that support the life within the agricultural system. Four types of anthro capital exist: 1) financial capital 2) human capital 3) social capital and 4) physical capital. Financial capital is more of an accounting concept. It represents accumulated claims on goods and services, built up through financial systems. Human capital refers to the capability of individuals based on their knowledge. Social capital yields beneficial collective action. It consists of shared knowledge. Physical capital is the stock of human made resources.

Each of the characteristics of sustainable agriculture enumerated in table 3.1 can be interpreted following the above mentioned types of capital. Starting with the first positive aspect, “equilibrium among the ecological cycles” can be interpreted as equilibrium among the goods and services produced by the natural capital; “production of the basic agricultural products for the present and future generations” can be interpreted as natural and human capitals. “Providing decent living and working conditions” means providing the adequate social and physical capital; “maintaining product capacity of natural resource” can be interpreted as sustaining the capacity of the natural capital. Finally, “the self- reliance of the farmers” can be understood as to be the interdependent work of farmers with other stakeholders of the agricultural system in order to sustain both the human and social capitals. We will come back to these ideas again in chapter five, particularly in connection with the development of our conceptual model.

3.6 Conclusion

This research sees four challenges for the sustainable agriculture domain. The first is to understand the true nature of agricultural sustainability. We must better educate ourselves in sustainability issues because it has been studied that simply by passing practices and policies often fail (Brady 1990). Second, is creating, and testing improved technologies and systems to increase rural incomes, alleviate hunger, and conserve natural resources. Technologies and systems must be adapted for the local level of aggregation. Third, to create an economic and social environment that encourages the adoption of new technologies and systems. It is important to encourage the development adoption of technologies and practices that favor sustainability within agriculture. Fourth is to establish linkages between the different stakeholders involved in agriculture. Such linkages will further the concept that the path to sustainability does not lie in one single actor but on interdisciplinary collaboration from a broad range of disciplines. An example of such collaboration is the study of the human dimension of sustainable development and sustainable agriculture. According to Gardner and Stern (2002), the behavioral elements of environmental related problems have been ignored by physical scientist and government policy makers. They argue that in spite of the agreement on the fact that human activity as the cause of several environmental threats, there are few studies that consider the human dimension or what we call in chapter 4, a knowledge approach.

Disparate groups now agree that the current development path, though possible for a while, is not sustainable (World Bank 2004). Governments and civil society support different conventions and demand more public and private accountability. The private sector is more committed to sustainable development, with greater use of triple-bottom-line accounting. Development agencies are shifting to more participatory and integrated approach. In the literature of sustainability, it is found that a systemic approach is needed if one studies sustainable issues. The study of (sustainable) agricultural systems should be based on an approach that allows looking for connections among all aspects of these systems: an overall and integrated or, what we also call systems, approach. A systems approach provides an overview and manner of understanding how the different relationships on a specific context work. Nobody has a single right vision of what the “right” sustainable way of practicing agriculture entails. Nobody yet knows how best sustain the earth’s ecosystem for us and for future generations. It would be vain to think that there is a single right vision or a best way to sustain agricultural systems or what kind of system should be sustained. Underlying the (shallow) consensus that appears to be triggered by the introduction of the sustainability concept, there are still norms, values and interests in conflict. Even if we would be able to point a single direction to achieve sustainable agriculture, it would vary greatly from situation to situation and be likely to change over time as circumstances continuously change.

While we could easily spend all our time debating about the definition of the concept of sustainable agriculture, we believe that sustainable agriculture stands as a valid and vital concept. We accept the importance of sustainability as a guiding principle for the attitudes and practices that should prevail in agricultural practices. Nevertheless, what it means in operational terms—how it may be applied—is by no means clear. We suggest that we give highest priority to discussing operational issues— practical applications of the concept. With that in mind, we offer the following observation as a basis for the discussions to follow in the rest of this study. Because knowledge determines individual behavior and because social systems consist of individuals, knowledge can influence a system’s sustainability (Jorna, 2006). The next chapter will develop a knowledge approach for assessing sustainable agriculture and to follow it consistently to study farmer’s decision making processes. Understanding the concept of sustainable agriculture (also as a mental construct) and its application can provide the basis for thinking about and planning for the future of agricultural systems.

4 KNOWLEDGE

4.1 Introduction

As Viederman (1990) points out, sometimes we are self-satisfied with our wisdom in moving ahead with sustainable agriculture. However, sometimes that wisdom is difficult to transfer and it requires not only speaking about sustainable agriculture but also understanding its meaning for different stakeholders to satisfy their needs. In the agricultural sector, the main stakeholders are those directly linked with agricultural practice and activities: the farmers. Thus, a key issue is not to establish just a conclusive list of sustainability indicators, but to investigate and understand the concepts that farmers associate with sustainable agriculture and find ways as how to achieve sustainable agriculture. It can be argued that in order to explore knowledge of the meaning of sustainable development for different actors, a framework based on knowledge theory and cognitive science can be used. We propose in the following a knowledge approach to study sustainable agriculture. Knowledge as a criterion for guiding agriculture as it responds to change. We believe that considering the concepts that farmers include in each model of farming practice will help the transition from a conventional to a sustainable agriculture. The different worldviews in classical and sustainable agriculture can be studied, and evaluated, adopting a knowledge perspective.

4.2 Knowledge and its Relevance in Agriculture

From a knowledge perspective, we can distinguish in the European Union (Fig. 4.1) a transition in knowledge approaches for every model of agriculture going from a conventional model of agriculture towards a sustainable model. Before 1945, there was a traditional model of agriculture. After the war period, the agricultural policy was based on maximizing the production yields in order to avoid food shortages. This goal developed into a situation that fosters a maximization of possible profits. In this period, the knowledge approach was oriented towards increasing production. The focus was on private companies and universities that helped the farmer and relied on public and private investments (van der Ploeg and Roep, 2003). Since 1990, it is now recognized that the one-way top-down approach — where the farmer is told what to do — is insufficient to allow bottom-up interactions and feedbacks necessary for 'natural' diversification and system adaptation (Morgan and Murdoch, 2000). The top-down approach still dominates current visions of sustainable development of the agro-sector. Consequently, scientists and policy makers have typically defined indicators of sustainable development only. We argue

that the "top-down" focus in the "old thinking" approach has to be adapted such that practice is embodied in the farmer's knowledge structures as part of the farmer's models of the world.
The complexity of sustainable agriculture requires individuals to possess knowledge regarding agricultural systems in order to make them behave in a sustainable way. Additionally, individuals require the acquisition of new insights and forgetting old customs that stand in the way of sustainability. Hence, individual knowledge constitutes an extensive realm of accumulated practical knowledge and knowledge-generating capacities that is needed if sustainability and development goals have to be reached. This asks for a bottom-up approach, meaning an approach starting from the individual interpretation of that context. Therefore, it seems to be relevant to understand what knowledge farmers have about sustainable agriculture. These models might provide a basis for planning, deciding and acting or reacting upon in specific circumstances. Farmers should possess agricultural related knowledge structures that are used to interpret events or to initiate, formulate or recommend plans, projects, or decisions. Hence, it is also relevant to identify mind-settings and reasoning patterns used by farmers to interpret this knowledge. In the future nothing less than a new sustainability paradigm will bring about changes on the scale needed. This is a "push" for change. We suggest such a (new) model would challenge both the viability and desirability of conventional values, economic structures and social arrangements" and its success will depend on major agents of change acting synergistically.

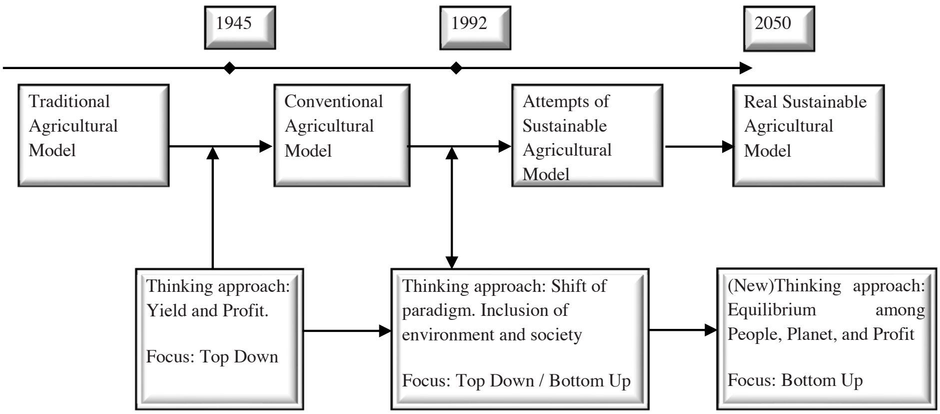


Figure 4.1 Knowledge transition in agriculture

4.2.1 Knowledge Approach

McElroy (2008) identifies knowledge as the key factor regarding sustainability. Some authors have included this knowledge discussion in the literature on sustainability. For instance, Laukkanne (2000) explored the notion of sustainability of structure and dynamics of different municipalities in Finland. Byrch et al. (2007) explored the meaning of sustainable development held by business leaders who promote sustainability. Boone Jr. et al. (2007) reported the knowledge that extension educators have concerning the dimensions of sustainable agriculture. Knowledge is something that individuals have and exhibit in all kinds of activities. In the Western world, philosophical debates about knowledge in general start with Plato's formulation of knowledge as "justified true belief." Although this formulation is questioned, we will not discuss the history of philosophy on knowledge. Finding a precise definition of knowledge in terms of suitable and clear terms may be difficult (Jorna, 2000; Morton, 2007). Knowledge differs from information and data. Data can be defined as raw numbers, images, words, and sounds that are the result of observation or measurement (Hislop, 2005). The raw numbers from a soil analysis, for instance, can be used as a basis for making calculations or drawing conclusions regarding the sowing plan. Generally, data are available in a form that is suitable for computer storage or processing. Information consists of data arranged in a structured pattern or meaningful order (Mitchell, 2000). For example, a soil analysis could be analyzed by means of a particular statistical technique. Knowledge, however, is information combined with experience, context, interpretation, reflection, and perspective (Davenport et al., 1998), and adds a new level of insight and meaning (Frappaolo, 1997). In short, knowledge is information, which is interpreted, evaluated and forms the foundation of human action.

Knowledge may be viewed from several perspectives. Knowledge has been described as "a state" with knowing being a condition of understanding gained through experience or learning (Schubert et al. 1998). The perspective on knowledge as a state of mind focuses on enabling individuals to expand their personal knowledge and apply it to the organization's needs. A second view defines knowledge as an object (Carlsson et al. 1996; McQueen 1998; Zack 1998). This perspective posits knowledge as a thing to be stored and manipulated (i.e., an object). Alternatively, knowledge can be considered as a process of simultaneously knowing and acting (Carlsson et al. 1996; McQueen 1998; Zack 1998). The process perspective focuses on the application of expertise (Zack 1998). Further, knowledge can be considered as a condition of access to information (McQueen 1998). According to this view, knowledge must be organized to facilitate access to and retrieval of content. This view may be thought of as an extension of the view of knowledge as an object, with a special emphasis on the accessibility of knowledge objects. Knowledge can be viewed as a capability with the potential for influencing future action (Carlsson et al. 1996). Watson (1998) suggests that knowledge is not so much a capability for specific action, but the capacity to use information; learning and experience result in an ability to interpret information and to ascertain what information is necessary in decision-making. Finally, knowledge can also be viewed as existing in the individual or the collective (Nonaka, 1994). Hence, at the core of any activity resides individual knowledge. Any activity, in turn, starts with knowledge; it permits the elaboration of knowledge and generates knowledge as an outcome on a daily basis. According to Orasanu and Conolly (1993), two fundamental contentions in decision performance in everyday situations are that 1) the decision process is a joint function of two factors: (a) features of the task, and (b) the subject's knowledge and experience relevant to that task and 2) past decision research has neglected these two elements in varying degrees. Klein et al. (2003) discuss factors that characterize cognitive process in naturalistic or “real world” contexts, such as an agricultural system. These factors are frequently ignored in cognitive science research and consist of the following:

1. Ill structured problems;
2. Uncertain dynamic environments;
3. Shifting, ill-defined, or competing goals;
4. Action/feedback loops;
5. Time stress;
6. High stakes;
7. Multiple players;
8. Organizational goals and norms.

1. Ill structured problems: Real decision problems rarely present themselves in the neat, complete form the event model suggests. The decision maker will generally have to do significant work to generate hypotheses about what is happening, to develop options that might be appropriate responses, or even to recognize that the situation is one in which choice is required or allowed. A farmer for example, might be clear about the products he should grow regarding the customers requirements but spend a great deal of time testing new hypothesis about underlying weather or soil conditions in order to decide how to grow a specific product. Moreover, there is no single correct or best answer. Simon (1991) noted that ill-structured problems frequently are made more ambiguous by uncertain dynamic information (feature 2 below) and by multiple interacting goals (feature 3 below).

2. Uncertain dynamic environments: Naturalistic decision making typically takes place in a world of incomplete and imperfect information. Information may be ambiguous or simply of poor quality. Simon (1972) explains this through his concept of bounded rationality. People make quite reasonable decisions based on the information they have, but they don’t have perfect information. People rarely see the full range of possibilities they have. People do not foresee (or choose to ignore) the impacts of their actions on the system where they are part of. For example, farmers do not know how much product will be sowed by other farmers in a particular season. They much less know the weather for a particular season.

3. Shifting, ill-defined, or competing goals: it is rare for a decision to be dominated by a single, well-understood goal or value. We expect the decision maker to be driven by multiple purposes, not all of them clear, some of which will be opposed to others. In the case of sustainability, the farmer is faced with three different sets of goals: social, environmental and economical.

4. Feedback loops: The traditional decision models are concerned with an event, a point in time at which the single decisive action is chosen. In a naturalistic context, in contrast, it is much more common to find an entire series of events, a string of actions over time that are intended to deal with the problem, or to find out more about it, or both. This is not just a matter of gathering information until one is ready for the decisive action. Farmers for example, may consider different ways to try a new fertilizer. They may want to try on a small extension of their land first. If the product works, they might be willing to try a bigger extension and so on until they are convinced that the new product really works. These action/feedback loops may make the problems easier (when outcomes are tightly coupled to actions) or harder (when outcomes are loosely coupled to action), but they certainly require a new view of how decisions are made.

5. Time stress: Decisions may be taken under significant time pressure. This may be in the very short term at the level of needing action in hours or minutes, or of a compressing review of crucial farming strategy in to a single month. This time pressure has several obvious but important implications. First, decision makers in these settings will often experience high levels of personal stress, with the potential for exhaustion and loss of vigilance. Second, their thinking will shift; characteristically in the direction of using less complicated reasoning strategies (Payne, Bettman, and Johnson, 1988). For example, farmers may take decisions (like the use of a specific chemical product for the soil) that might affect the environment in the long term due to stress caused by the entry into force of a new policy for the next growing season.

6. High stakes: Farmers decisions involve outcomes of real significance for them: the loss of their heritage, or the future performance of their farm. Obviously, there are plenty of everyday decisions where the stakes are much smaller than the loss of their heritage.

7. Multiple players: Many of the situations that a farmer faces involve not a single decision maker, but several, perhaps many, individuals who are actively involved in one role or another. In the agricultural system farmers have contact with other farmers, advisors, suppliers, governmental institutions and with the civil society. It can be hard to make sure all stakeholders share the same understanding of goals and situational status so that relevant information is brought forward when needed in the decision process.

8. Organizational goals and norms: The organizational setting is relevant to the decision-making process in two ways. First, the values and goals that are being applied will not be simply the personal preferences of the individuals involved. Second, the organization may respond to the decision maker's various difficulties by establishing more general goals, rules, standard operating procedures, "service doctrine," or similar guidelines. In the case of farmers, they normally are associated to a broader body of farmers that can establish some special procedures.

In addition to looking at naturalistic task conditions, it is also important to understand how people use their knowledge and experience in coping with complex problems. This research is concerned with decisions made by farmers who know a lot about the problems within the agricultural domain. That does not mean they are expert decision makers (such as decision analysts), but they are familiar with the tools and information sources relevant to their domain. Research on expert problem solving has shown that a significant aspect of what specialists do when functioning in their everyday complex environments is to use their knowledge and experience to size up the situation, determine if a problem exists, and, if so, whether and how to act upon it. (Chi et al. 1988, Klein, 1989). What is needed, and what this study is about, is research and theory that will contribute to a fuller understanding of how people use their knowledge and experience to make decisions in complex dynamic cognitive situations (e.g. sustainable thinking). Consequently, our next theoretical thread, cognition, helps explain how knowledge is used between individuals.

The perspective of our approach towards agricultural sustainability is the individual, the farmer. Farmers create and share knowledge with emphasis on the domain of (sustainable) agriculture. Farmers also make decisions, solve problems. We take the perspective of Faber (2006) where he argues that farmers are human decision makers and therefore information processing systems (Newell & Simon, 1972; Card et al., 1983). A farmer involved in decision-making concerning his products equals a human decision-maker or human problem-solver, a term that denotes humans involved in decision-making or problem solving relating to a certain task environment in general. As an information processing system, the human decision-maker exchanges information with his task environment.

Through information exchange with his task environment, the human decision-maker creates representations of the task environment in his cognitive system. The amount of effort a decision-maker needs to exercise in order to resolve a problem is determined by the structuredness of the problem, heavily influenced by the decision-maker's current problem-related knowledge. If the decision-maker possesses knowledge that is applicable for the present problem, he is expected to have no troubles making his decisions; he is able to create a suitable "problem space". Within this "problem space", initial, end or final, and intermediate state can be represented, as well as the appropriate state transitions. Regarding a decision-maker's current knowledge, the factors of importance are among others the number of years of experience within a certain field and the level of education. In contrast, the decision-maker will fail to make a decision when he lacks the required knowledge. In this case, the decision-maker needs to learn and acquire additional knowledge. Cognition can help at describing how knowledge is processed in human minds.

4.3 Cognitive Science

As with systems theory, we do not present an in-depth discussion on the theory of cognition. Instead, we want to present how sustainability can be considered as content in an individual's mind. Boden (2006) presents a comprehensive review of the history of cognitive science. A history of that endeavor is traceable back to Aristotle. Aristotle proposed that the mind at birth is a blank slate, or tabula rasa. As a blank state, it contains no knowledge of the objective, empirical universe, or of itself (Beth, 1959). The study of cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. Its intellectual origins are in the mid-1950s when researchers in several fields began to develop theories of mind based on complex representations and computational procedures. Its organizational origins are in the mid-1970s when the Cognitive Science Society was formed and the journal Cognitive Science began in the 1976 (Cognitive Science Society, 2011). The study of mind remained the province of philosophy until the nineteenth century, when experimental psychology developed. Wilhelm Wundt and his students initiated laboratory methods for studying mental operations more systematically. Experimental psychology became dominated by behaviorism, a view that virtually denied the existence of mind. According to behaviorists such as J. B. Watson, psychology should restrict itself to examining the relation between observable stimuli and observable behavioral responses. In 1956, George Miller summarized numerous studies, which showed that the capacity of human thinking is limited. He proposed that memory limitations can be overcome by recoding information into elements, called chunks. We are talking about mental representations that require mental procedures for encoding and decoding the information. In addition, Noam Chomsky (1967) rejected behaviorist assumptions about language as a learned habit and proposed instead to explain language comprehension in terms of mental grammars consisting of rules. At this time, computers had been around for only a few years, but pioneers such as John McCarthy, Marvin Minsky, Allen Newell, and Herbert Simon were founding the field of artificial intelligence. The researchers mentioned can be viewed as the founders of cognitive science.

In the past decades, cognitive science has made significant advancements in understanding mental structures and processes underlying knowledge representation, acquisition and construction. Our research is based on a human-centered approach that characterizes humans as information processing systems (Newell and Simon, 1972). Humans use knowledge to perform (solve) activities (tasks). Haber (1969) designated two assumptions of the information-processing approach in psychology. His assumptions are called (1) the stage assumption and (2) the limited capacity assumption. It is assumed in the stage assumption that the processing of information can be broken down into sub processes or stages. That is, the time interval between the stimulus and the response can be divided up into smaller intervals, and each of these corresponds to some subset of mental events between stimulus and response. In the course of the stages the original information undergoes successive transformations. Newell and Simon (1972) define several components that shape the human information processing system (IPS). The theory of a human as an information processing system has played an important role in building Cognitive Science.

4.4 Information Processors

In line with cognitive science the concept of cognitive psychology emerged as an outcome of computer technologies by assuming that the computer can provide a new paradigm for psychology. Cognitive psychology therefore, analyses human mental processes with the aim of understanding human behavior. Information theories of perception, attention, memory, emotions and personality were developed (Weisser, 1967). Humans are viewed as an “active processors” of information eternally striving to sum up and interpret the incoming data and to interpret and reproduce the information stored in its memory through a variety of algorithms and strategies' (Tikhomirov. 1988). In this trend, psychology at large was declared a science of information processing. Although artificial intelligence, cognitive science, and cognitive psychology have different aims and methods of investigation, they all share an understanding of human thinking as information processing in which we can also place the study of sustainable agriculture within a knowledge perspective.

In order to understand humans as information processing systems it is useful to have a firm grounding in the cognitive processes that the user undergoes (Preece et al., 1994). Humans perceive information, use knowledge, and make decisions. Understanding this, allows the researcher to predict and explain the interaction that occurs between the farmer and its (agricultural) system. A cognitive system model first explains human information processing in terms of the integration of a sensory register (i.e., input device such as a keyboard on a computer); a working memory to process, retrieve, and store information (i.e., an operating system); and a long-term memory (i.e., a storage device). This processing system needs good sensory input, proper training, and the ability to pay attention to stimuli and to make accurate discriminations among stimuli. While problems within each component and their connections contribute to errors, the model also shows how mistakes are due to the influence of various factors on mental functioning.

In a cognitive system there exist different components that comprise the human information processing system (IPS), Newell and Simon (1972) formulated the following 8 components:

1. A set of elements called symbols;

2. A symbol structure consists of a set of tokens (equivalently, instances or occurrences) of symbols connected by a set of relations;

3. Memory is an architectural component of the information processing system, capable of storing and retaining symbolic structures;

4. An information process is a process that has symbol structures for (some of) its inputs and outputs;

5. A processor is a component of an IPS consisting of:

a. a fixed set of elementary information processes (eip's);
b. a short-term memory (STM) that holds the input and output symbol structures of the eip's;
c. an interpreter that determines the sequence of eip's to be executed by the IPS as a function of the symbol structure in STM;

6. A symbol structure designates an object if there are information processes that recognize the symbol structure as input and either:

a. affect the object directly; or
b. produce as output, symbol structures that depend on the object;

7. A symbol structure is a program if:

a. the object it designates is an information process; and
b. the interpreter, if given the program, can execute the designated process;

8. A symbol is primitive if its designation is fixed by the elementary information processes or by the external environment of the IPS.

With the components of the IPS defined, we can now study the actual system. In the first stage of information processing, a certain amount of information is registered or entered in the system. Information can stay in a register for a brief time, but the longer it stays there the weaker it gets (decays). While information is in a sensory register, the processor comes into play. One of the characteristics of the processor is pattern recognition, a complex process involving contact between the information in a sensory register and previously acquired knowledge. That is, a pattern is recognized when the sensory aspects of the pattern are in some way equated with meaningful concepts. Thus, pattern recognition can be thought of as assigning meaning to data. It serves the function of briefly holding information in the system in what is called "veridical" form—that is, in much the same form as was initially presented--until it can be put into a new form and sent further into the system. Closely related to pattern recognition is the process of attention. Selective attention makes it possible to focus on, or tune in, the relevant information and to filter out the rest. Thus attention ensures that the more important information is brought into the limited-capacity system.

The smallest units of information held in the memories of the information processing system are symbols. In principle, an infinite vocabulary of symbols may exist in the human long-term memory. Human memory is described as being associative. Associativity is achieved by storing information in LTM in symbol structures, each consisting of a set of symbols connected by relations. Through learning, certain stimuli or patterns of stimuli from the input channels come to be designated by particular symbols and become recognizable. These recognizable stimuli patterns are called chunks. These stored symbols then serve as the internal representation for the corresponding stimulus patterns or chunks, and the chunks, on recognition, evoke their stored designators. These chunks are not innate, but are learned. The IPS has a short-term memory of a very small capacity. It appears that the contents of STM at any given moment consist of a small set of symbols, each of which can designate an entire structure of arbitrary size and complexity in LTM. The STM seems to be immediately and completely available to the IPS processes. The STM can be defined functionally as comprising the set of symbols that are available to an IPS process at a given instant of time (Newell and Simon, 1972).

We have discussed what a (human) information processing system is. It has been argued (Marr, 1982; Pylyshyn, 1984; Jorna, 2006) that for any information processing system to be understood completely, it must be described at three different levels of analysis. "Almost never can a complex system of any kind be understood as a simple extrapolation from the properties of its elementary components . . . If one hopes to achieve a full understanding of a system . . . then one must be prepared to contemplate different levels of description that are linked, at least in principle, into a cohesive whole, even if linking the levels in complete detail is impractical" (Marr, 1982, pp. 19-20). The concept of levels of analysis or levels of aggregation is fairly well structured and established. It offers the possibility of distinguishing different structures in the mind and processes at various temporal scales. It offers the possibility to focus on a specific stance in order to explain cognitive behavior.

4.4.1 Mental Representations

As Nonaka and Takeuchi (1995) argue, knowledge is situated in the mind of the individual. Hence, with respect to the optimum use of knowledge, the role of the individual as the carrier of this knowledge is important. From a cognitive perspective, an individual has the ability to perceive, interpret, and evaluate acquired knowledge (Jorna, 2006).Traditional cognitive psychology has focused on cognition as computational rules, treating the mind as an information-processing system that acts on and manipulates (formal) symbols. But the computer metaphor and the view of cognition as information processing forced an emphasis on an abstract, algorithmic, and logical characterization of the mind (Newell and Simon, 1972) and ignored the role of individual's interaction with the environment in the understanding of cognition. A development in cognitive science relating the interaction of brain, body, and environment has arisen as a way to describe cognition emerging and unfolding beyond just the brain and highly situated within particular contexts (Clark and Chalmers, 1998; Hutchins, 1995; Rowlands, 1999). Externalization means the placement of something outside its original boundary. In the context of cognition, this implies that what is normally construed as cognition within the brain can occur outside of the head (Clark, 2001), much like Norman's (1980) notion of knowledge in the head and knowledge in the world. A simple example involves note taking or working out a problem on paper. Conventionally, taking notes is not considered "remembering," but in the present context, it is seen as an externalized cognitive function (see Clark & Chalmers, 1998). Specifically, cognition occurs not in a vacuum but rather within and through a task and a context (see Clark, 2001; Clark & Chalmers, 1998; Hutchins, 1995; Rowlands, 1999). The emphasis is on the practice of cognition "by which internal representations are incomplete contributors in a context-sensitive system rather than fixed determinants of output: and they too focus on the ongoing interactive dance between brain and world" (Sutton, 2006, p. 282). Individual knowledge building involves the particular actions taken for building one's own knowledge. This process involves individual mental model construction. The notion of a "mental representation" is, arguably, in the first instance a theoretical construct of cognitive science or cognitive psychology.

The central hypothesis of cognitive science is that thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures. Most work in cognitive science assumes that the mind has mental representations analogous to computer data structures, and computational procedures similar to computational algorithms. Cognitive theorists have proposed that the mind contains such mental representations as logical propositions, rules, concepts, images, and analogies, and that it uses mental procedures such as deduction, search, matching, rotating, and retrieval (Jonson-Laird 1993; Jorna, 1990). As this research aims at understanding the source of knowledge in agriculture, we focus on the farmer as level of analysis. Farmers use perception, the meanings of the words and sentences, the significance of the propositions that they express as knowledge. Farmers represent this in a mental model of the world. The conclusions farmers draw depend on the models which they hold. In any case, at the heart of reasoning are mental representations. Knowledge representation refers to the general topic of how information can be appropriately encoded and utilized in models of cognition. Representations functionally describe what goes in the mind of individuals.

Anderson (1990) argues that a correct representation is essential in problem solving; a representation enables us to describe human cognition, to study the structure of knowledge and the meaning of a problem that needs to be solved. Thus, a representation can be seen as a crucial concept in studying knowledge and the mind in general. However, the concept of representation is also a matter of debate. Blacker (1995), stresses that knowledge is too multifaceted and complex to such a simplistic approach. While there is disagreement about the nature of the representations and computations that constitute thinking, the central hypothesis is general enough to encompass the current range of thinking in cognitive science, including connectionist theories, which model thinking using artificial neural networks. Mental representation thus holds a crucial place in studying cognition.

4.4.2 Reasoning by Mental Representations

“To be intelligent is to be able to think and to be able to think is to be able to reason” (Johnson-Laird, 2006). Reasoning is a central component of cognition, in that many other cognitive processes depend on it. Theories of comprehension invoke reasoning to explain how people predict upcoming information in a text or a conversation and how they link unexpected information to what they have gathered so far. Theories of memory invoke reasoning to explain how people reconstruct past events from the fragmentary clues they are able to recall (Bechtel and Graham, 1999). Human reasoning can be described as a set of cognitive processes by which people take an initial set of information and generate inferences that extend beyond the original data. In this sense, the expectations, generalizations, and assertions people reach in interpreting events and situations can all be considered the result of reasoning. The inferences people produce can range from conclusions justified by formal procedures to sketchy hunches supported by varying degrees of evidence. Reasoning ranges from the”hard" thinking it takes to formulate an answer to a difficult question or resolve a complex situation to the nearly automatic inferences and predictions that occur in the planning and execution of everyday activities. The first approach to study reasoning is the traditional distinction between deductive and inductive forms of reasoning (Kurtz et al., 1999). In deductive reasoning, conclusions are entailed or follow directly from the application of logical forms to premises. An additional usage of the term refers to a top-down direction of inferencing from abstractions to specific cases. Inductive reasoning refers to the generation of inferences that are not guaranteed within a formal system. These inferences are essentially guesses made probable by a set of evidence. Induction also refers to the bottom-up construction of high-level abstractions derived from observation of specific cases. Within this traditional approach the idea of reasoning is often equated with the notion of purely logical processes that operate independent of content. Within psychology the study of reasoning has focused largely on the use of content-independent logical rules (Johnson-Laird and Byrne, 1991; Rips, 1994). However, other research shows that the content being reasoned about influences people’s reasoning ability, even for tasks to which logical rules are applicable (Cheng

& Holyoak 1985, Cosmides 1989). Partly because of these findings, there has been considerable interest in how people learn and use rich domain representations such as theories and mental models. According to the mental models theory of reasoning (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991; Johnson-Laird et al., 1989), human reasoning is more concerned with the truth conditions in the world (semantics) than about logical form (syntax). The argument is that people do not reason using abstract rules, but rather they construct and combine mental models and generate inferences consistent with those models.

According to Jonson-Laird (1983) individuals construct mental representations of the world and they do so by employing, mostly tacitly, mental models. There are recursive mental processes that enable human beings to understand discourse, to form mental models of the real and the imaginary and to reason by working on and manipulating such models. For instance, we can exemplify how people may think about soil:

a) An average person: It forms a thin layer over the surface of the earth;
b) A fertilizer's supplier: It serves as a substrate supporting plant growth and as a nutrient reservoir;
c) An agricultural engineer: It is essential for crops. It is not only a support for plant roots, but also the site of many physical, chemical, and biological processes.

Fundamental in our discussion about knowledge is the focus on the individual farmer and on his/her mental representations regarding sustainable agriculture. In section 2.2 we discussed that the agricultural system is a dynamic system influenced –in first instance- by the farmers. Farmers need to adapt their behavior to the changes in the system and often they need to acquire or create new knowledge. This means that farmers need (new) knowledge content of various aspects of sustainable agriculture. This in turn implies that farmers need processes to acquire and incorporate (new) knowledge into their practices. In other words, the knowledge that a farmer possesses can be distinguished in terms of content and processes. This distinction is discussed in the next section.

4.5 Content and Process of Knowledge

The distinction between knowledge in terms of content and processes forms the basis of two key concepts in our research. Knowledge of Sustainability (KoS) and Sustainability of Knowledge (SoK), (Jorna, 2006; 2010). KoS indicates 1) Knowledge content about the actual state of agriculture and causes that underlie environmental, social, and individual problems, and 2) The knowledge by which such problems can be resolved. On the other hand, SoK focuses on the knowledge processes that govern the production, creation,use and integration of knowledge.

4.5.1 Knowledge of Sustainability

Knowledge of sustainability is about the content of knowledge (Faber 2006, Jorna 2010). In the case of sustainable agriculture, the central issues are, as it has been discussed in section 3.4.2 knowledge about planet, people and profit. This kind of knowledge is used to fulfill the needs of the agricultural system to be updated and adjusted continuously. Farmers –the main actors in an agricultural system- have to cope with the changes of the system to maintain a balance between their farm and its environment. The provision of all agricultural system begins at the level of land that is managed by a single individual or group of individuals. In order to manage the land well –decision making on this specific context- a farmer combines the natural, economical, and social resources at his disposal. We discussed in section 3.4 that a systemic approach is needed if one studies sustainable issues. The study of (sustainable) agricultural systems should be based on an approach that allows looking for connections among all aspects of these systems (an overall and integrated or, what we also call, systems approach). As a matter of fact, development agencies are shifting to a more participatory approaches (UNSD, 2010).

A systems approach provides an overview and manner of understanding how the different relationships in a specific context work. Based on system's theory in Table 4.1, we present five systemic qualities that can be used to distinguish a sustainability oriented knowledge structure from the knowledge structure of classical farming. First, we have the systemic quality of focusing on the big picture of the system. Systems are frequently so complex that their behavior cannot be deduced from the properties of the elements alone. Whenever a disturbance occurs in the system, a cascade of impacts occcurs (McKinney and Schoch, 2003). The components of the agricultural system discussed in section 2.2 function together as a whole and not independently. As a second systemic quality we have the focus on interconnections. The interactions of the elements within the agricultural system operate together as a set of interdependent relationships (Richmond, 2005). For instance, soil quality and energy savings may seem to be non-related at first sight but if the soil is in good condition, less pulling power is needed. That in turn saves fuel. This is how soil quality and energy consumption could be closely linked. The third systemic quality focuses on feedback loops.

Feedback describes a closed chain of corelations (Meadows, 2008). For example, the more soil is eroded, the fewer plants are able to grow, so the fewer roots that can hold the soil, so the more soil erodes, so less plants can grow. Cooperation is the fourth systemic quality. Cooperation is the process by which the actors of a system work together to achieve the global properties. In other words, components that appear to be independent work together to create a highly complex system (Richmond, 1991). Cooperation among farmers can be important because a group has more knowledge than an individual. It can also contribute to personal growth as the farmers are challenged to acquire new knowledge. Last, we have a long time perspective. The impacts due to disturbances within the system become less predictable over time. Soil erosion, for example, can proceed for a long time without farmers realizing (if they only focus on the effect on crop yield) until the topsoil is exhausted to the depth of the root zone of the crop. Beyond that point, erosion can cause yields to decrease.

Table 4.1 Elements of a sustainability oriented knowledge structure on an agricultural system

Less sustainability oriented mindset	**More sustainability oriented mindset**
Focus only in specific units of the system	Focus on the big picture of the system
Focus on "straight" chains in the system	Focus on interconnections within the system
(Lack of) focus on different interactions	Focus on feedback loops between units
Working in isolation or in a hierarchical manner.	Cooperation, coordination.
Short time perspective (here and now)	Long time perspective (there and then)

4.5.2 Sustainability of Knowledge

Sustainability of Knowledge denotes the processes to acquire new knowledge and integrate this knowledge into human behavior (Faber 2006, Jorna 2010). SoK is about how individuals learn, how knowledge is transferred, and how it is developed. This asks for a bottom-up approach, meaning an approach starting from the individual interpretation of that context (see section 4.2). Since the farmer is portrayed as an active processor, who explores, discovers, reflects, and constructs knowledge our perspective is not so much to transmit information, but rather to encourage knowledge formation and development of cognitive processes for judging, organizing, and acquiring new information. In this study, we discussed that we advocate a bottom-up approach in order to achieve sustainable agriculture.

Table 4.2 compares the top-down and bottom-up approach but now within a cognitive perspective where the farmer is considered as the most important actor within the agricultural system. The bottom up approach incorporates a view on the farmer as an individual with an information processing system (section 4.4). The communication with experts (suppliers and agribusiness) is not just as receivers of information but also as processors of information where farmers develop and reflect on their own knowledge. As we develop the methodology (chapter six), we keep this comparison in mind, and reflect on the role that farmers can play in order to build a sustainable future within agriculture.

Table 4.2 Comparison of the Top-Down and the Bottom-Up approaches

Top-Down	Bottom-Up
Expert Centered	Farmer Centered
Expert Present Knowledge	Farmer Discover and Construct Knowledge
Learner as Receiver and Memorizer	Farmer as Processor
Expert Structures Learning	Social Interaction Provides Instructional Scaffolding
Reactive	Proactive
Mechanistic	Systemic

4.6 Knowledge Modeling

In the previous sections we argued that knowledge is an important factor whilst studying sustainable agriculture. Our focus is on individual (farmer) behavior, on the knowledge regarding "people", "planet" and "profit" and in the way this knowledge is used. Therefore, it is necessary that the knowledge farmers express is made explicit. Knowledge engineering is the field that is responsible for the analysis and design of knowledge systems (artificial or human) and it is thus concerned with representing and implementing the expertise of a chosen application domain (usually on a computer system). A knowledge-engineering approach is CommonKADS (Schreiber et al. 2000). The main idea of the CommonKADS is that knowledge that resides in the minds of individuals can be represented in a detailed manner. CommonKADS distinguishes agents and knowledge elements. Agents can be either humans or complex computerized artifacts. Knowledge elements are elementary parts of a knowledge domain. A knowledge element is a representation within the individual's mind (Newell 1990). CommonKADS defines a knowledge domain as a set of knowledge elements that is necessary to execute a certain task. In order to describe knowledge, CommonKADS builds on six models (Organization Model, Task Model, Agent Model, Communication Model, Knowledge Model and Design Model). Although interesting, we do not go in detail into the CommonKADS methodology, but focus on the definition of knowledge domain to develop the conceptual model in chapter five.

A major contribution of the CommonKADS approach is its proposal for structuring the so called Knowledge Model, which describes the knowledge used by an agent (Schreiber et al. 2000). Basically, this model describes a static and a dynamic view of knowledge. The knowledge model operates on three types of knowledge required to solve a particular task: domain knowledge, inference knowledge and task knowledge. Domain knowledge describes the structure and content of the domain, and it is represented in the system through ontologies (i.e. a set of concepts). Inference knowledge is modeled in terms of operations on domain knowledge (inferences) and in terms of roles (role is a label of a domain knowledge class which participates in particular inference operation). Task knowledge is modeled as a hierarchy of tasks. In summary, domain knowledge specifies the knowledge domain (for example, knowledge of sustainable agriculture), the inference knowledge represents the reasoning steps or cognitive activities that are executed when a farmer performs a task; task knowledge describes what inferences follow upon each other. For example, when farmers are confronted with a task, like planning their next sowing season, they perform a series of cognitive activities in order to draw conclusions to achieve the best possible plan with the concepts they have. The farmer may draw conclusions based on the type of product that is to be grown, the type of soil, the environmental legislation and the profit that is expected.

In section 3.4 we adopted the "view from space" perspective in order to look at an agricultural system. Now, we include the domains of knowledge a farmer has within this view (fig. 4.3). An agricultural system consist of a collection of actors that have their knowledge (own mental representations) regarding the agricultural system as a whole. The main actors in the system (farmers) have a cognitive model that supports representations (content) and operations (reasoning process) on the agricultural system. The farmer also possesses personal characteristics, e.g., attitudes, norms and values. Personal characteristics and experiences have influence on the creation of different mental representations in the farmers. In this respect, there have been studies regarding the characteristics (or traits) that influence farmers in order to adopt (or not) specific farming practices (Lauwere et al. 200; Pieters, 2005). However, one of the existing gaps is the need for more research regarding how individual actors think about and in terms of sustainability (Jorna, 2010). This also involves obtaining the knowledge from farmers, coding and indexing the knowledge (for later retrieval), and capturing it. Without a systematic routine for capturing knowledge, a farmer might not benefit from its best knowledge being captured. To be useful, it should be easy to retrieve the captured knowledge. In order to transfer and transform the knowledge from individual minds to some explicit knowledge representation - that enables the effective use of the knowledge- it is necessary to explore knowledge acquisition methods in organized approaches. These approaches may help to extract from farmers a better understanding of the complex relationships between cognition, agriculture, and other factors, such as people, planet and profit. In the following section, we will discuss how to elicit the knowledge a farmer possesses.

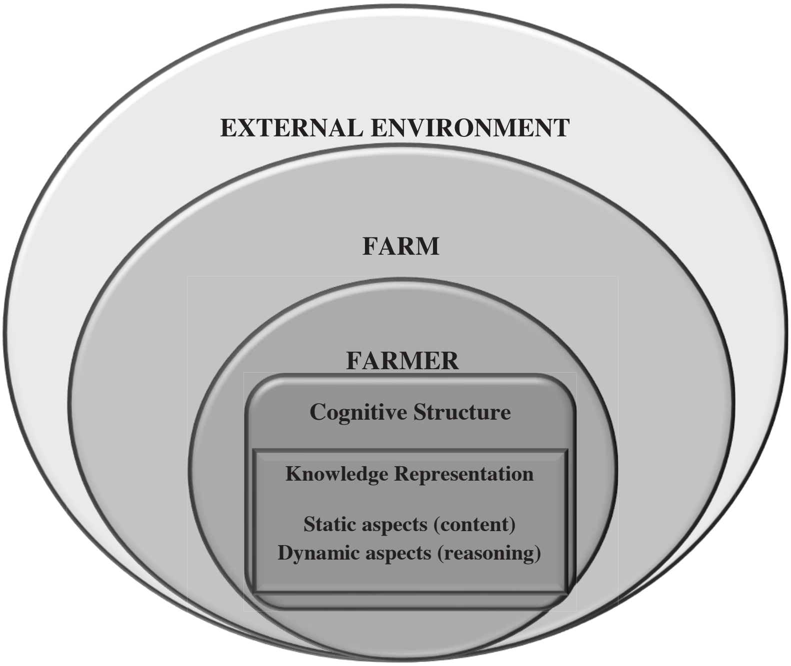


Fig 4.3. Knowledge representation embedded on the farm system components

4.7 Knowledge Elicitation

Since the agricultural system can be considered as a collection of individuals, it is also relevant to focus on knowledge at an individual level. In the context of a farm, the role of the individual (the farmer) is essential because farmers are the carriers of knowledge. However, the following question arises: "How can knowledge about sustainability be effectively elicited from an expert? Although the cognitive literature addressed the issue of knowledge, the focus was largely on the question of representation and various theoretical conceptualizations of knowledge structures such as semantic networks, scripts, prototypes, and schemata but not in the naturalistic context (e.g., Anderson, 1995; Klein et al., 2003, see section 4.2). The most relevant cognitive research on expert problem solving and memory organization did not directly address elicitation, but provided some hints or guidelines that could help guide the future development of the methods. Additionally, the favored cognitive measures of reaction time and error rate were inadequate as a solution for knowledge elicitation (e.g., Bailey and Kay, 1987). Although mainstream cognitive research and theory offered little in the way of direct solutions to knowledge elicitation and how to organize the obtained data, they were nonetheless influential in the development of methods for knowledge elicitation, particularly in the areas of problem solving expertise and knowledge representation.

In general, knowledge elicitation techniques are capable of providing rich information regarding the concepts, relations, facts, rules, and strategies relevant to the domain in question. The techniques differ in terms of their procedures, as well as their emphasis on one type of knowledge or another. No technique is guaranteed to result in a complete and accurate representation of an expert's knowledge, although the goal is to model the expert's knowledge, not to extract or reproduce it in its entirety. The major drawback of these methods is that they can be costly. Rich data are associated with lengthy data collection sessions, unwieldy data analysis, and interpretation difficulties. In section 4.5 we have discussed that we focus on content and process of knowledge. Knowledge content refers to what is known about sustainability within agriculture. Cognitive mapping is a technique that allows exploring the different concepts that a domain such as sustainable agriculture acquires among different individuals. Process of knowledge refers to how content knowledge is thought about and applied. Protocol Analysis is a technique in order to get grip on thinking that allows exploring how to manipulate the concepts they have in static aspects. We will discuss cognitive mapping and protocol analysis in the following sections. The first provides an operationalization of content and the second of reasoning.

4.7.1 Cognitive Mapping

Cognitive mapping may be defined as a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in their everyday spatial environment (Downs and Stea, 1973). Cognitive map is the term used to refer to one's internal representation of the experienced world. Cognitive mapping includes the various processes used to sense, encode, store, decode, and use this information. In psychology, "cognitive map" is a term developed by Tolman (1948) to describe an individual's internal mental representation of the concepts and relations among concepts. This internal mental representation is used to understand the environment and make decisions accordingly. Cognitive maps are regarded as "internally represented schemas or mental models for particular problem-solving domains that are learned and encoded as a result of an individual's interaction with their environment" (Swan, 1997 pp. 188). Therefore, cognitive maps provide a presentation for what is known and believed, and exhibit the reasoning behind purposeful actions (Fiol and Huff, 1992).Most of human action is based on habits. They are not pondered but executed automatically, based on experience and knowledge about the (social) environment and the individual’s capacities. Knowledge about physical capacities, social resources and the ongoing relation with them is represented in cognitive maps and schemas (see, e.g., Sandler and Rosenblatt, 1962; Lazarus and Folkman, 1984; Markus and Wurf, 1987; Baldwin, 1992). Again, while cognitive maps can be created and modified by conscious intent, they also arise and operate without conscious intent, manifested in cognitive structures reflecting values, emotions and behavior. In contrast, cognitive mapping techniques are used to identify subjective beliefs and to portray these beliefs externally (Fiol & Huff, 1992). The general approach is to extract subjective statements from individuals, within a particular problem domain, about meaningful concepts and relations among these concepts, and then to describe these concepts and relations in some kind of graphical layout (Swan, 1997). The outcome of a cognitive mapping technique is usually referred to as a cognitive map. Cognitive mapping is an umbrella term encompassing the following mapping techniques

- Causal mapping

Causal mapping is one of the most commonly used cognitive mapping techniques in investigating the cognition of decision makers in organizations (Swan, 1997). Causal mapping is derived from personal construct theory (Kelly, 1955). This theory posits that an individual's set of perspectives is a system of personal constructs and individuals use their own personal constructs to understand and interpret events. A causal map represents a set of causal relationships among constructs within a belief system. Through capturing the cause effect relationships, insights into the reasoning of a particular person are acquired.

- Semantic mapping

It must be pointed out that causal assertions are only part of an individual's total belief system. Some cognitive mapping techniques can be used to identify other relations among concepts. Semantic mapping, also known as idea mapping, is used to explore an idea without the constraints of a superimposed structure (Buzan, 1993). To make a semantic map, one starts at the center of the paper with the main idea, and works outwards in all directions, producing a growing and organized structure composed of key words and key images. Around the main idea (a central word), five to ten ideas (child words) that are related to the central word are drawn. Each of these "child" words then serve as a sub-central word for the next level drawing (Buzan, 1993). In other words, a semantic map has one main or central concept with tree-like branches.

- Concept mapping

Another cognitive mapping technique is called concept mapping. Ausubel (1968) emphasized the importance of prior knowledge in being able to learn about concepts. Drawing on this theory, Novak (1993) concludes that existing cognitive structures are critical for learning (new) concepts. A concept map is a graphical representation where nodes represent concepts, and links represent the relationships between concepts. The links, with labels to represent the type of relationship between concepts, can be one-way, two-way. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts. Concept mapping is useful in generating ideas, designing a complex structure, communicating complex ideas, aiding learning by explicitly integrating new and old knowledge, as well as assessing understanding or diagnosing misunderstanding (Jonassen, Beissner, & Yacci, 1993).

Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts. Linking phrases specify the relationship between the two concepts. Within concept maps, it is frequent that the concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. The hierarchical structure for a particular domain of knowledge also depends on the context in which that knowledge is being applied or considered. Therefore, it is best to construct concept maps with reference to some particular question we seek to answer, which we have called a focus question. In the present study, we presented the farmers with a question that is relevant in their agricultural domain: “What factors are important while planning for the next sowing period?” The concept map may pertain to some situation or event that we are trying to understand through the organization of knowledge in the form of a concept map, thus providing the context for the concept map. Another important characteristic of concept maps is the inclusion of cross-links. These are relationships or links between concepts in different segments or domains of the concept map. Cross-links help us see how concepts represented on the map are related. In the creation of new knowledge, cross-links often represent creative leaps from the part of the knowledge producer.

4.7.2 Protocol Analysis

Protocol analysis is a rigorous methodology for eliciting verbal reports of thought sequences as a valid source of data on thinking (Someren et al. 1994). In sections 4.3 and 4.4, we discussed the cognitive approach which focuses in higher-level cognitive processes and how thinking allows individuals to generate solutions to novel tasks. It has also been discussed how individuals are able to apply acquired knowledge and procedures to novel problems, such as mental multiplication. Information processing theories (Newell and Simon, 1972) proposed computational models that could reproduce the observable aspects of human performance on well-defined tasks through the application of explicit procedures. Protocol analysis has emerged as one of the principal methodologies for eliciting verbal reports of thought sequences as a valid source of data on thinking in cognitive psychology (Crutcher, 1994), cognitive science (Simon and Kaplan, 1989), and behavior analysis (Austin and Delaney, 1998). As further evidence of its validity, protocol analysis now plays a central role in applied settings, such as in the design of surveys and interviews (Sudman et al., 1996) and user testing of computer software (Henderson et al., 1995). Finally, several interesting adaptations of verbal-report methodology are emerging in the study of text comprehension (Pressley and Afflerback, 1995) and education (Renkl, 1997).

The central assumption of protocol analysis is that it is possible to instruct subjects to verbalize their thoughts in a manner that does not alter the sequence of thoughts mediating the completion of a task, and can therefore be accepted as valid data on thinking**.** The theoretical and methodological controversies about verbal reports do not refer to people's ability to recall part of their thought sequences. The controversies have centered on efforts to go beyond the sequence of thoughts, to analyze their detailed structure through introspection, and infer the processes controlling the generation of new thoughts. In fact, all major theoretical frameworks concerned with thinking have advocated the use of verbally reported sequences of thoughts (Ericsson and Crutcher 1991). For example, the behaviorist John B. Watson pioneered the use of "think aloud," and the gestalt psychologist Karl Ducker established it as a major method. Based on their theoretical analysis, Ericsson and Simon (1993) argued that the closest connection between thinking and verbal reports is found when subjects verbalize thoughts generated during task completion. When subjects are asked to think aloud, some of their verbalizations seem to correspond to merely vocalizing "inner speech," which would otherwise have remained inaudible. Non-verbal thoughts can also be often given verbal expression by brief labels and referents. If the act of verbalizing subjects' thought processes doesn't change the sequence of thoughts, then subjects' task performance should not change because of thinking aloud. In a comprehensive review of dozens of studies, Ericsson and Simon (1993) found no evidence that the sequences of thoughts (accuracy of performance) were changed when subjects thought aloud as they completed the tasks, compared to subjects who completed the same tasks silently. However, some studies showed that think-aloud subjects would take somewhat longer to complete the tasks--presumably due to the additional time required to produce the overt verbalization of their thoughts**.**

4.8 Conclusions

In this chapter, we have presented a knowledge approach based on cognition and mental processes towards sustainable agriculture. Fundamental to the study of knowledge is the notion that individuals hold knowledge within structures in their cognitive or mental system. According to Jorna (2007), the crucial distinction between information and knowledge is interpretation. This activity is carried out by people as an information processing system (Newell and Simon, 1972) consisting of cognitive architecture, mental representations, and processes on these representations. Internal representations or mental objects reflect the content of a farmer's knowledge and are located ultimately in the brain. In studying mind, researchers examine human thinking through mental representation. The cognitive structure or architecture is the first core element in a theory of human cognition. The second core element is the content, available in terms of mental representations, cognitive representations, and models (Newell, 1990). The concept of cognition offers the link to study the knowledge structure that people use to make assessments, judgments, or decisions involving opportunity evaluation also in the agricultural domain.

The goal of developing sustainable agriculture is the responsibility of all participants in the system, including farmers, laborers, policymakers, researchers, retailers, and consumers. Each group has its own part to play, its own unique contribution to make to strengthen the sustainable agriculture community. Nevertheless, the farmer remains as the principal actor in the agricultural system. Agriculture has been considered through the years as having the specific function of production where the main objective is to produce commodities (food and fibers) and the main goal has been to increase the land productivity in order to provide more food and to have more economic profit. This model drove achievements of knowledge in Europe after World War II and the spread of the green revolution beginning in the 1960s. Nowadays there is an increasing recognition that the current agricultural model requires revision. This leads to rethinking the role of knowledge in achieving development and sustainability goals within agriculture. We have distinguished two key concepts that help to rethink the role of knowledge within agriculture: Knowledge of Sustainability (KoS) is required to ensure that the actions of the farmers contribute to the improvement of sustainable agriculture. Sustainability of Knowledge (SoK) refers to ways of creating, exchanging and preserving knowledge. It is required to ensure that knowledge is distributed and preserved among farmers who, at the end, are the main actors in order to achieve a sustainable agriculture. We use the CommomKADS methodology in order to understand how knowledge is represented in the mind of farmers. CommonKADS describes two views of knowledge: static and dynamic. We included this description into the view from space model which provides a systemic view of the agricultural system where the mental representations in the mind of a farmer are embedded (see section 3.4). However, it lacks operational detail. Although difficult, it is indirectly possible to map out knowledge content and reasoning. Two widely accepted knowledge elicitation methods are cognitive mapping and protocol analysis. Through the knowledge approach we presented in this chapter we built a conceptual model in chapter 5 where we aim at identifying concepts linked with sustainable agriculture (static aspects) and to get some insights in the way of reasoning among the farmers (dynamic aspects).

5 CONCEPTUAL MODEL

5.1 Introduction

The previous chapters set up the framework of theories on how knowledge of sustainability is processed within farmers´ minds. Conventional agriculture has led to higher yields and profitability. It has also led to creating negative environmental impacts. Sustainability has emerged as an alternative for agricultural systems to address the many constrains faced by conventional agriculture. Since our study focus on the individual, we argue that the adoption of a sustainable practice is ultimately a reasoning decision made by a farmer base on his knowledge structure. Therefore, cognitive factors are fundamental in agricultural actions, as can be seen from the conceptual model we develop in the present chapter.

5.2 Knowledge at the Heart of Sustainability

In chapter two, we discussed the positive and the negative aspects of the agricultural practices of the late 20th century. Conventional 20th century agriculture took industrial production as its model, and vertically integrated agri-business was the result. The industrial approach coupled with substantial subsidies, made food more abundant and cheap in Europe. Nevertheless, farms are biological systems, not mechanical ones, and they exist in a social context in ways that manufacturing plants do not. Through its emphasis on high production, the industrial model has degraded soil and water, reduced the biodiversity, increased dependence on oil, and driven more and more acres into the hands of fewer farmers crippling rural communities. Chapter 3 presented what has been the response to the extractive industrial model. The response is mostly ecology-based. However, no agriculture is sustainable if it is not also profitable, able to provide a family income and a good quality of life. As the idea of alternatives to industrial agriculture evolve so must the agricultural system and the farmers who sustain it. Hence, sustainable agriculture challenges farmers to think about the long-term implications of practices and the broad interactions and dynamics of agricultural systems.

In chapter 4, we approach agriculture and sustainability from the social perspective of sustainability focusing on individual knowledge. Individually, farmers must decide for themselves what methods are best for their own situation. Farmers use knowledge about maintaining soil fertility, stopping soil erosion, avoiding soil compaction, protecting their own crops from pests, using adequate amounts of water. This is to be accomplished while balancing profitability, stewardship of natural resources, and the well-being of the rural community. In order for farmers that aim at practicing sustainable agriculture to be successful in managing their farms, there must be knowledge that is available to them (e.g. information on agricultural research, new technologies and innovations that are available) enabling them to understand the needs and challenges that they are facing. In section 4.5, we discuss that for agriculture to be sustainable it needs that farmers possess knowledge about sustainability within agriculture as well as in other domains (KoS). Jorna (2010) has developed a reference model for organizations, knowledge, and sustainability. We adapt this model to the knowledge of sustainability within agriculture in order to focus on the individual farmer. (figure 5.1).

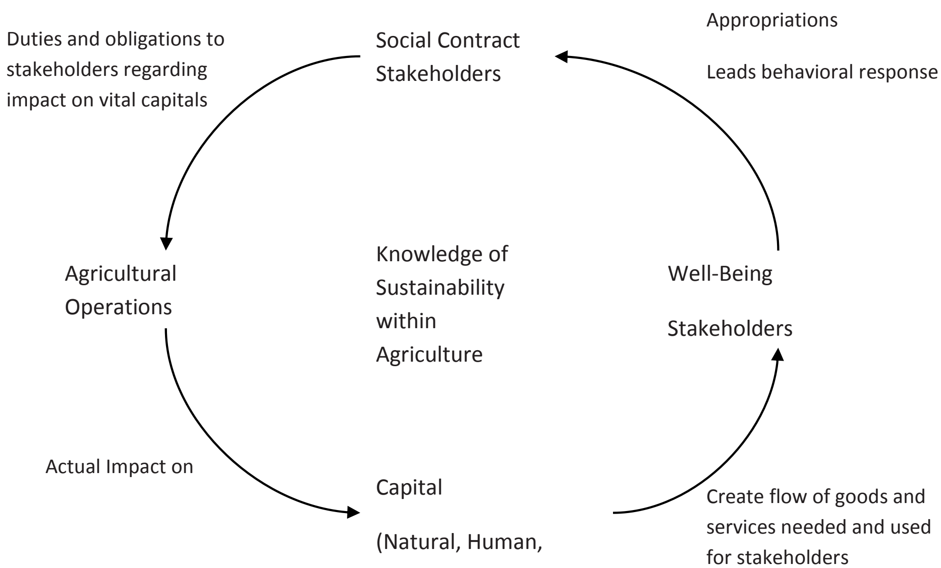


Fig 5.1 Knowledge management and sustainability in the farm context

The reference model has five key aspects: knowledge of sustainability, capital, well-being, social contract, and agricultural operations.

Knowledge of Sustainability (KoS)

The core of the model is the knowledge an individual farmer possesses. In the case of this research, we focus on the knowledge of sustainability (KoS) within agricultural practices. In section 4.5, we stated that KoS relates to knowledge content which concerns sustainability about planet, people, and profit. The existing knowledge regarding sustainable agriculture is mostly about environmental issues. There is little knowledge available from and within the social aspect.

Specifically, there is a little understanding regarding which terms individuals use when they think about sustainability. Furthermore, KoS has an impact on the different forms of capital (which comprises different types: natural, human, social, and constructed).

Capital

According to McElroy (2008), the study of sustainability includes the human impacts on various kinds of capitals. In the context of this research, the different kinds of capital concern natural, human, social and constructed capitals. These capitals create flows of goods and services needed and used for well-being. The role of knowledge of the different types of capital is important to identify and specify norms regarding environmental limits and social needs, which are necessary to realize well being.

Well Being

Well-being is most commonly used in philosophy to describe what is good for a person. Yet, conceptual distinctions are not sufficiently clear within psychology (Diener, 2000). Nevertheless, it is probably fair to say that one's life goes well to the extent that one is contented with it. Farmers and their stakeholders appropriate the well-being. The perceived well-being leads to behavioral responses towards the functioning of the agricultural system. We concur with the idea of the Wadden Academy (Kabat et al. 2009) where well-being is understood as the coexistence of a sustainable economy, a livable community and a quality landscape where the farmer operates.

Social Contract

According to Gazendam (2006), a social contract is a socially shared unit of knowledge (i.e., a “root concept” to which norms are attached). This concept refers to the agreements made within the agricultural system by all the stakeholders in relation to their rights and duties. These agreements promote the functioning of the agricultural system. For example, there are norms related to the social construct of property that are inherited by the specific instance of that social construct in the form of the social construct “land ownership”. An example of these rules is that only the land owner can sow in a particular piece of land unless the owner gives permission to other persons to do so.

Agricultural Operations

This aspect relates to the management of all kinds of capital. We discussed in section 3.4.1 that sustainable agriculture meets environmental, economic, and social objectives simultaneously.

Knowledge is needed in order to manage the different forms of capital. Agricultural operations have an impact on the different types of capital. These impacts affect the well-being of the different stakeholders and the cycle of the reference model and so it starts again.

In our research, KoS is about the content of sustainability within agriculture. Nowadays, this knowledge is mostly filled with knowledge about ecological issues (soil, land use, irrigation techniques, pollution issues, etc.). Farmers in their practices can use existing KoS. KoS can be also used by different stakeholders (i.e. in the policy making arena). This knowledge is important and relevant if one wants to tackle problems within sustainable agriculture. The transformation of agriculture into a more sustainable system requires that farmers adopt a sustainable mindset. However, the factors that determine whether a farmer has such a mindset are unclear. Farmers do not answer to a hierarchical structure like employees in a private or public company. While they might respond to external authorities such as a bank, their overall survival and well-being depends on their own decisions. Farmers make daily decisions which impact the farm's operations. While some farmers might seek professional advice to help make good decisions, their decisions also reflect their operational skills (diversification), technical knowledge (educational level) and past experiences (age and expertise). For example, choosing a mode of farming depends on matching the resources such as the prevailing climate, the type of soil with options for profitable crop production. The aim of the study is to understand and to comprehend what knowledge farmers have and what they do, in terms of knowledge process, with the knowledge they possess.

5.3 RESEARCH QUESTIONS

As reviewed in section 5.2, we argue that research and development effort in agriculture is dependent on the farmer's knowledge structure. There is a need to understand the knowledge structure of the different stakeholders involved in the agricultural system, starting with the main actors, the farmers. Hence, the following research questions have been formulated (see chapter 1).

1) *What is the relation between agriculture, sustainability, and knowledge?*

2) *What kind of knowledge aspects do farmers have regarding sustainability?*

3) *How is it possible to elicit knowledge of farmers?*

    3a)What content of knowledge do (specific type of) farmers have regarding sustainability?

    3b)What reasoning mechanisms do (specific types of) farmers use to favor sustainability?

In chapter four, we discussed the importance of knowledge within the mind of individual farmers. Structuring of knowledge and reasoning in the agricultural system involves deciding what to do. A problem of reasoning about actions is given in terms of an initial situation, a terminal situation, a set of feasible actions and a set of constraints. A farming task, such as, for example, deciding which product to grow next year or which practice to use, consists of finding the best acceptable sequence of permissible events and actions that will enable the farmer to move from making a sowing plan to actually accomplishing by sowing in the most convenient way.

5.4 Influence of Personal Characteristics of Farmers in Agricultural Practices

We sought to answer the research questions through two activities: a comprehensive review of pertinent literature and interviews with farmers in order to elicit their knowledge structure. In section 3.4, we adopted a three dimensional view in order to look at a farm. We use this view in order to develop our conceptual model. Farmers are the main actors in the agricultural system. Therefore, the adoption of a sustainable practice is ultimately a decision made by the farmer based on his/her knowledge structure. It thus makes sense that the personal characteristics of a particular farmer may have an important role in the way that farmers process knowledge. The study of knowledge processing is on one hand the study of specific skills and on the other hand the study of the deep structures that surround the main knowledge processes. These deep structures include the organization and processing of knowledge. Depending on how farmers organize and processes their knowledge they will favor (or not) sustainable practices. The conceptual model shown in its basic form captures the effect of the personal characteristics on the knowledge structure of individual farmers. The adoption of a sustainable practice in agriculture is expected to be influenced by the knowledge structure of a farmer (fig. 5.2).

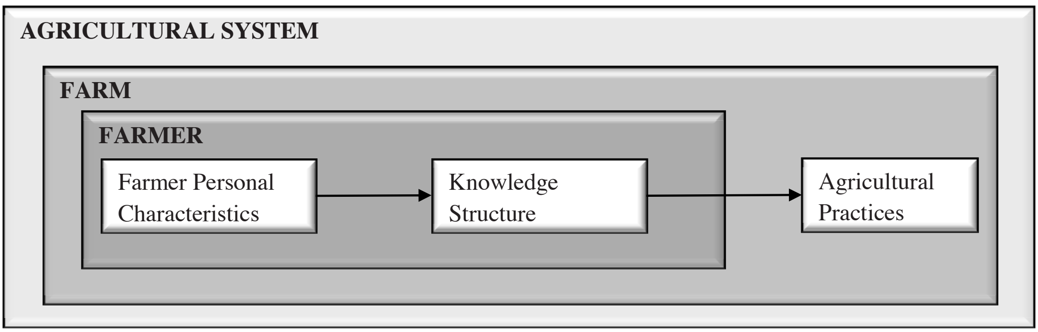


Fig. 5.2 Basic Conceptual Model

We also focus on relevant significant individual characteristics related with the knowledge structure of a farmer including diversification of activities, education, age, and expertise.

5.4.1 Diversification

As the position of agriculture in the economy is changing, farmers may seek to enhance their household income from different products. Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops (Culas and Mahendrarajah, 2005). The adoption of crop technologies is influenced not only by resource related factors but also by institutional and infrastructure factors. Similarly, government policies - both supportive and regulatory in nature - affect both the input and output prices. Likewise, special government programmes may also affect area allocation and crop composition. Although the factors that influence the area allocation decision of farmers are all important, they might differ in terms of the relative importance across farm groups.

5.4.2 Education Level

According to the American Heritage dictionary (2011), education is defined as the process by which society deliberately transmits or acquires its accumulated knowledge, skills, and values from one generation to another. Hence, education may be a relevant area for awareness building of the need for sustainable development. If people are not convinced that they should strive for a sustainable future, for more efficiency and more sufficiency in their day-to-day life, then all political programmes, concepts, and rhetoric will change nothing. This is true for all three dimensions of sustainability– economical, social, and ecological. It has to be said that in EU documents on sustainable development education is rarely mentioned. Mulder and Kupper (2006), state that agricultural education has been an essential factor in the success of agricultural development in the Netherlands. Agricultural education for many years has been aimed at increasing subject knowledge of farmers. Agricultural education institutes are no longer exclusively oriented towards agricultural and horticultural companies: they also focus on land use, gardening, nature conservation, environmental protection, geo-information systems, and stimulating biodiversity, to name a few.

5.4.3 Age and Expertise

While researchers usually have the depth of an educational background to devise comprehensive programs based in scientific or technological information, they often lack the intense personal knowledge of specific problems or conditions that are very real and unique to a given agricultural area. This is where farmers have been able to step in, as scientists and extension workers have increasingly realized the value of local farmers' knowledge. This is a valid assumption considering that farmers are usually the individuals most closely in contact with the land or agricultural system in question. Take, for example people that are farming in areas with unpredictable seasonal changes. An all-encompassing national or regional plan will typically lack the flexibility needed for success, whereas the farmers with local knowledge are usually able to make the adjustments necessary for a productive season despite outside influences. They have a practical understanding of their crops, land, which could never be matched by theoretical models or policies only (Röling and Jiggings, 1998; Jiggins, 2000).

5.4.4 Elements of Knowledge Structure

In section 4.3 and 4.4 we attempted to show that individuals have and acquire knowledge. The next step is to know what knowledge they have. In our study, we work directly with farmers to elicit knowledge because they are the principal actors in the agricultural system. In section 4.7 we discussed that the elicitation of expert knowledge and its effective transfer to a useful knowledge-based system is complex and involves a diversity of activities. We have selected two widely used knowledge elicitation methods, cognitive mapping and protocol analysis, whose results reflect the knowledge structure of a farmer. Cognitive mapping is a largely visualisation technique by which participants set down concepts and then link them together into a map (see 4.7.1). The cognitive map of a farmer can be described in terms of 1) The number of concepts that can be classified within categories (frequency of use). These concepts refer to KoS, in our case these concepts are derived from the Triple Bottom Line approach (people, planet and profit) as explained in 3.4.2. 2) The use of a concept. Frequency of use can indicate how environmental, social or economic concepts are positioned within the knowledge structure of a farmer. 3) Map density. It is defined as the number of links within a map divided by the maximum number of possible links between the map concepts. It is useful to compare structural complexities of maps, but it does not provide any insight into measuring differences in the content of a map (Langfield and Wirth, 1992). In section 3.3.1 we discussed that any system can transmit disturbances from one part to the system to another. In other words, the parts of a system operate as a set of interdependent relationships. We can get insights in the response of a farmer to agricultural issues by looking at the number of links (among the concepts within a map) that are identified by the farmers. For example, a farmer may identify as possible outcome of using fertilizers that it

may have a positive impact on the yield of a product on a specific season. However, at the same time, the use of fertilizers may have a negative impact in soil and/or in water quality.
Think aloud-verbal protocols allow gaining information regarding the knowledge structure of a farmer during task execution (see 4.7.2). Verbal protocols can be described in terms of 1) Number of words (related to KoS) given in the protocol. This allows having an indication of how a farmer organizes his/her knowledge structure. Verbal protocols provide information about the particular knowledge domains that are used to make inferences, for example when solving an assignment that confronts the farmer with an agricultural issue. 2) Characterization of knowledge structures. This knowledge structure can be profiled with respect to the systemic qualities derived from our review in sustainability: cooperation, feedback, integration, interconnections and time horizon. The details of the systemic qualities are described in 4.5.1.

5.4.5 Sustainable Agricultural Practices

There is no general agreement in the literature as to what specific practices constitute a sustainable agricultural system. Nevertheless, a sustainable agricultural system can be seen as a system involving a combination of practices -rather than a single practice used in isolation-, which integrate the three pillars of the Triple Bottom Line approach (section 3.4.2). For the purpose of this study, we focused on the relationship between the farmers' knowledge structure and their participation (or not) within a project where stewardship of both natural and human resources (including economic profitability) is important. In other words, the knowledge structure of farmers may influence their participation in local projects that promote sustainable practices such as soil and biodiversity conservation, collaboration among farmers and acquiring KoS.

Extending our basic conceptual model, the dependent variable of the model represents whether a farmer participates (or not) in a sustainable agricultural project. The participation in a sustainable project is influenced by both the content and process of knowledge that farmers hold. Knowledge structures are affected by factors that are included within the individual characteristics of the farmer.

5.5 Hypotheses

The extended conceptual model assumes that the following farmer personal characteristics cause the knowledge structure to change: educational level, degree of diversification of business and products, farming experience and age. In addition, the model assumes that knowledge structure influences the participation (or not) in projects aimed at promoting sustainability. Following the hypotheses drawn from this conceptual model are formulated as follows.

5.5.1 Education Level

For a farmer to adopt any practice, he must first become aware of it, obtain information as to how to implement it, and understand any potential benefits and/or drawbacks of adopting the practice. Educated farmers are more likely to consider adoption of sustainable practices.

H1a: Higher educated farmers and lower educated farmers differ in the number of KoS concepts that can be classified within each category (3P´s).

H1b: Higher educated farmers include more KoS concepts in their protocols than less educated farmers do.

5.5.2 Diversification of Products

Another individual characteristic is to have diversified operations, with multiple cropping systems and land uses. The challenge to growing certain commodities may influence the knowledge structure of the farmer due to the availability of alternative practices for them.

H2a: The more diversified the farmer the more complex the cognitive map.

H2b: The more diversified the farmer the higher the level of systemic qualities in the protocol's profile

5.5.3 Farming Expertise

We also expect farming experience to influence farmer's knowledge structure. A farmer with greater experience will have encountered more different situations and will thus have more to compare.

H3a: The average map density of experienced farmers and novice farmers differs.

H3b: The more expertise the farmer has the higher the level of systemic qualities in his protocol´s profile.

5.5.4 Age

Because of the farming history of old generations it is possible to think that age is a determinant to establish just monetary goals, so that older farmers are unlikely to consider environmental and social concepts as goals in their enterprise; old growers are "ready to retire" and "do not have the years to see some of the benefits."

H4: Older farmers and young farmers differ in the number of Profit concepts within their cognitive maps.

5.6 Conclusions

Agricultural research considers environmental implications, social issues, and economic growth within the agriculture sector. The objective of the proposed conceptual model is to show the relation between the personal characteristics of a farmer and the knowledge structure that farmers possess about sustainable agriculture. Besides, we study whether relationships exist between the farmer´s knowledge structure and the agricultural practices they undertake. Knowledge of sustainability in the context of agriculture was translated into four independent variables and five dependent variables. The way persons (farmers in our study) process knowledge is related to some personal characteristics. The propositions are summarized in figure 5.4.

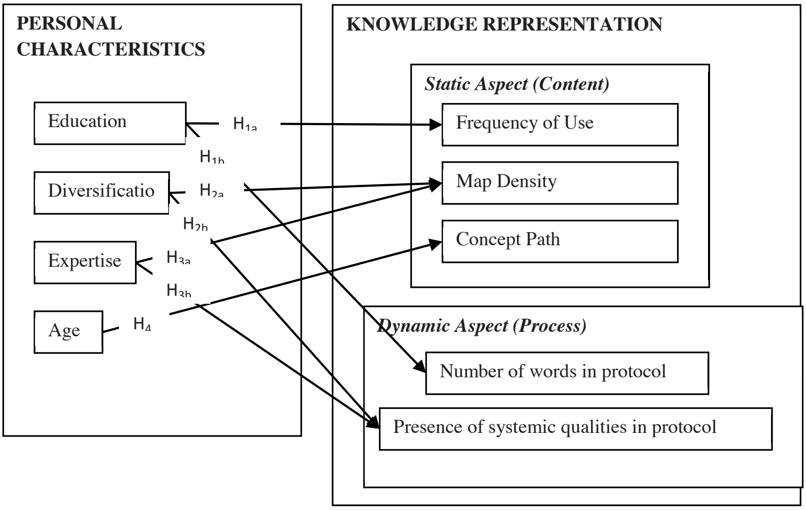


Fig. 5.4 Influence of farmers' personal characteristics on their knowledge structures

The left side of figure 5.4 indicates the personal characteristics that influence (some) of the knowledge structures (right side of the figure) in a farmer's mind. The hypotheses formulated will be tested in the data analysis chapter. In the following chapter, the chosen methodology is discussed.

6 METHODOLOGY

6.1 Introduction

The previous chapter provided an explanation of the conceptual model. This chapter provides an overview of the methodology that was used to achieve the research objective of this study. The objective of this study was to investigate how farmers think about and in terms of sustainable agriculture. For the empirical study, we worked in combination with laboratory in the agricultural sector in the Netherlands, BLGG (bedrijfslaboratorium voor grond- en gewasanalyse) AgroXpertus. The empirical study consists of two parts. The first part is an empirical study in order to get insights in the knowledge farmers have regarding sustainable agriculture. The second part is a larger study where two tools were developed in order to assess the cognitive processes carried out by farmers. Research questions were formulated to know farmer's concepts regarding sustainable agriculture and to understand the way farmers structure the knowledge they have. This chapter describes BLGG AgroXpertus, the population and the sample, the development of the instrument and procedures used in data collection and data analysis.

6.2 BLGG AgroXpertus

BLGG AgroXpertus has been the leading horticultural and agricultural analytical laboratory in The Netherlands for over 80 years. With its sampling, analytical, and advisory activities, BLGG AgroXpertus plays a supportive role in agricultural and horticultural procedures, thereby improving production and lowering production costs. BLGG AgroXpertus offers analyses and advice on nutrient content and quality of soil, manure, water, substrate, crops and cow feed to almost every Dutch farmer and crop grower. In addition, BLGG AgroXpertus analyses fresh products for food-safety purposes and offers advice regarding pesticide residue content and microbiology to primary producers as well as the (agro) food processing industry. BLGG AgroXpertus is based in The Netherlands and has branches in Belgium, Germany, Denmark, and Spain. The company has its own accredited sample collection and transport system, ensuring that samples are collected according to predefined guidelines and ensuring fast overnight transport to the different laboratories. Samples can be transported refrigerated if needed. In total, more than 500.000 samples per year are analyzed in accredited and highly automated BLGG AgroXpertus laboratories. BLGG AgroXpertus provides global end sampling, analysis, and advice through its own branches and / or a global network of affiliates.BLGG AgroXpertus offers its customers: 1) Help to improve productivity through practical operational advice. 2) Confidence in the advice through expert analysis and sampling. 3) Administrative convenience, through alliances and application of innovative techniques. BLGG AgroXpertus focuses on the areas of fertilization, feeding soil and crop health.

Plant pathogen analyses are carried out in the BLGG AgroXpertus laboratory situated in Wageningen. Annually, over 40.000 analyses of plant pathogenic nematodes from soil samples are performed by microscope and/or molecular detection techniques. The conserved morphology of nematodes makes microscopic analyses laborious, time consuming, and expert dependent. In close co-operation with Wageningen University (the Laboratory of Nematology) BLGG AgroXpertus therefore develops tests based on molecular bar coding for the detection of plant pathogenic nematodes in soil. The Laboratory of Nematology, funded by the Technology Foundation STW, constructed a DNA sequence database of over 1600 nematode species collected in the Netherlands (Holterman et al., 2006). This sequence information is used by BLGG AgroXpertus for the development of molecular tests for the detection of plant pathogenic nematodes. Comparative trials demonstrate that molecular tests have a higher detection rate than the traditional microscopic investigation of for instance the stem nematode (Ditylenchus dipsaci), onion white rot (Sclerotium cepivorum) and root knot nematodes (Meloidogyne spp.). Currently, the BLGG AgroXpertus laboratory analyses nematode extracts of over 20.000 soil samples each year with molecular techniques. Two examples where BLGG AgroXpertus has expertise are 1) Meloidogyne chitwoodi and M. fallax and 2) Globodera rostochiensis and G. pallida.

6.2.1 BLGG AgroXpertus and sustainability

BLGG AgroXpertus focuses specifically on the sustainability of agricultural areas, food safety and crop production. It combines existing methods with new tools and technologies into novel farming solutions addressing the biological, agronomical and economic diversity in the Netherlands and in the countries where it operates. BLGG AgroXpertus aims at contributing to the achievement of a sustainable balance between efficient crop production and the development of the ecosystem by jointly involving researchers and the key actors of the agricultural system (farmers, advisors, policy makers and actors of the food supply chain) in its assessments. Therefore, it invests resources in developing (new) knowledge and innovative products that lead to the balance between efficient crop production and ecologically sound and environmental friendly farming methods.

6.3 Population and Sample

As it has been discussed in the previous chapters, agriculture plays an important role to achieve sustainability in the Netherlands. Regarding arable farming, the Netherlands accounts for nearly a quarter of European vegetable exports. The Netherlands is among the world's three largest exporters of agricultural products next to the United States and France. In the Netherlands, potato cultivation accounts for approximately one-third of the value added in arable farming and for 25% of the arable land (Agricultural Economics Research Institute, 2003; FAO, 2008). After the United States, the Netherlands has the largest potato processing industry in the world (FAO, 2004). Notwithstanding its economic value, the potato sector has a downside. It has a major negative environmental impact because of the intensive mode of production and its extensive use of chemical crop protection (Jong and Snoo, 2002). Actors in the sector appear to have considered converting to ecological production but the envisioned conversion has not taken place yet on a large scale (Smit at al., 2006). As this study focuses on individual farmers, particularly on the knowledge they have regarding sustainable agriculture and the way in which farmers structure that knowledge, selecting potato growers that work with BLGG AgroXpertus was a natural choice. Hence, the sample for this study was derived from a database of arable farmers, which are customers of BLGG AgroXpertus from all over the Netherlands but especially from the regions: Flevoland, Groningen, Noord Brabant and Zeeland (Fig 6.1).

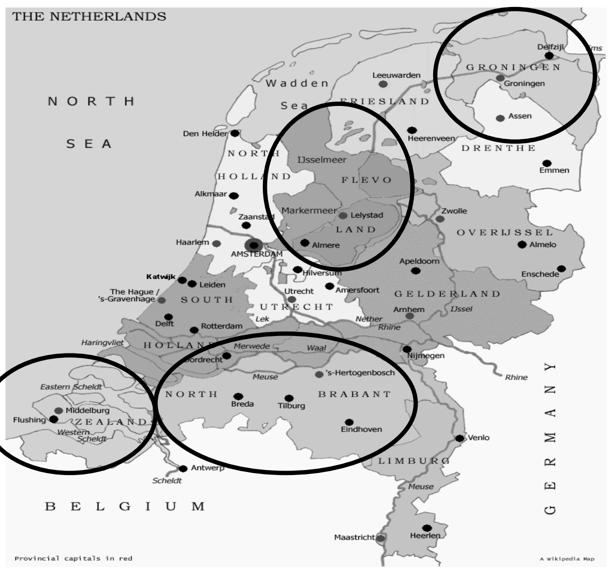


Fig. 6.1 Sampling regions (Flevoland, Groningen, Noord Brabant and Zeeland)

6.4 Procedures

Our study aimed at studying the determinants of a farmers' knowledge structure regarding sustainable agriculture. An instrument was developed in order to elicit knowledge content that represented the farmer's mindset. The instrument was developed based on the literature review as discussed previously (see Chapter 2, Chapter 3, and Chapter 4.) Nevertheless, because we wanted to improve in design and instrumentation and to provide a first understanding of the knowledge that farmers have regarding sustainability we decided to carry out a pilot study first.

6.4.1 Pilot Study

We wanted, with this pilot study, to test communication and gather information prior to the full study. A total of 11 participants were interviewed. The participants were farmers that work in the municipality of the Noordoostpolder in the Netherlands. The number of participants was selected based on the guidelines of Chess (1992). The participants were interviewed at their offices for one hour. The interview guide was pretested with a group of experts in the topic of sustainability working at the University of Groningen. In order to reproduce the interviews as exact as possible, each one of the meetings was voice recorded. The interview was transcript at the same day the interview was held. The transcription of each one of the interviews is not included in this thesis but they are available in the form of electronic files (the questionnaire is included in the Appendix I). The pilot study consisted of three parts. The first part is devoted to get general data such as age, years worked as a farmer and educational level. In the second, interviewees were asked a series of questions to assess the knowledge about sustainable agriculture and to see if the concept of sustainability was a priority for the farmers. The third part consisted of specific questions regarding their farming practices, the sources of information (regarding sustainability). In some of the questions, a 5-point Likert scale was used. We got insights in the sources that provide information regarding sustainable agriculture (Rosales et al., 2011). Hence, we continued our research efforts studying and evaluating the farmers' knowledge structure regarding sustainable agriculture with a more extensive and larger population in the knowledge elicitation study.

6.5 Knowledge Elicitation Instrument Elements

Once we were acquainted with the different concepts included within the literature review and when the pilot study was ready, we proceeded to start the knowledge elicitation study. The data was collected from June until October 2010. The participants were derived from a database of arable farmers, which are customers of BLGG AgroXpertus. We restricted the study to 80 farmers due to time and cost constraints. An instrument was developed to test the effects of educational level, diversification of activities, expertise, and age on the knowledge structure of farmers. The instrument also tested the effects of the knowledge structure with regard to the decision to participate on a specific project aimed at promoting sustainability. The instrument consisted of four parts. The first part was a questionnaire about the participant's background. In the second part cognitive maps were realised. The third part gauged the systemic qualities of a farmer's thinking through verbal protocols obtained by solving assignments specifically developed for the study. The last part consisted of a series of open questions. The instrument was applied at their offices for one hour and a half each and separately. The instrument was developed in Dutch. The instrument guide was pretested with a group of experts in the subject of sustainability working at the University of Groningen. Before conducting the full study, the instrument was further piloted with two farmers in the Groningen area and any difficult or unclear parts in the instructions were modified based on their feedback. No changes were made, however, in the content of the situations or responses used in the instrument. During the interviews, a group of assistants visited the farmers and applied the instruments. The group of assistants consisted of undergraduate students who were trained by the researcher and personnel from BLGG AgroXpertus in order to collect data. They were students from the Faculty of Business and Economics of the University of Groningen.

6.5.1 Questionnaire

The first part of our instrument contained questions about the participant's background, such as age, educational level, working experience and other professional activities. It also included questions about farm related information such as products grown by the farmer and production yield.

6.5.2 Cognitive Mapping

Once the first part was finished, we presented the farmer with software called "Domeinbeeldconstructor." This software makes possible the elaboration of a cognitive map. An important element of the instrument is that farmers arrange a set of concepts in terms of sustainability. This means that before the actual data collection could take place we needed to decide upon the objects that had to be arranged. In other words, we had to deal with the question which objects had to be evaluated in terms of sustainability. In sections 3.4 and 3.5, we discussed the Triple Bottom Line as a useful approach for our study. It takes into account social, ecological, and economical performances. We chose agricultural concepts that are representative of one of the elements included in the Triple Bottom Line approach (see table 6.1).

Table 6.1 TBL concepts included in the software

PLANET	PROFIT	PEOPLE
Soil Fertility	Product Cost	Training (Study Group)
Crop Protection	Sales Price	Consumer's opinion
Nitrogen	Revenue	Colleagues' Opinion
Phosphorous	Crop Yield	Supplier's opinion
Fertilization Plan	Product Quality	Local Community
Soil Nutrient Analysis	Market	Public opinion
Soil Pathogen Analysis		Family
Soil Texture		Future generations
Organic Matter		Regulation
Water (irrigation)		Wellbeing
Energy (fuel)		Independent Advisor
Nature		Legislation (CAP)
Crop Residue		Business Advising

Before starting to draw the cognitive map, each respondent received a stack of 32 cards. On each card the concept that they would use to elaborate the cognitive map was written. Before starting they had to make three smaller stacks of concept-cards: "an important stack," "a non-important stack" and an "in between stack." This helped the participants to become familiar with the concepts. This also could be used to validate the selected concepts to elaborate the cognitive map. The software program has already been used to study planners' knowledge structure in the Dutch Railways Company (Jorna et al., 1996). The software contains four windows. The first window is called "Start" (fig. 6.2). It welcomes the farmer. It also explains that the goal of the study is to get insights into the thinking differences that farmers have. It explains that in order to know these differences, the farmer should draw a map. The farmer is also reminded that there are no "right or wrong" maps; each map can be considered correct because it reflected a personal interpretation. The farmer is also presented with the other three windows. Before going into the second window, the farmer is asked to think about the most relevant factor to plan the next sowing season of his most important product.

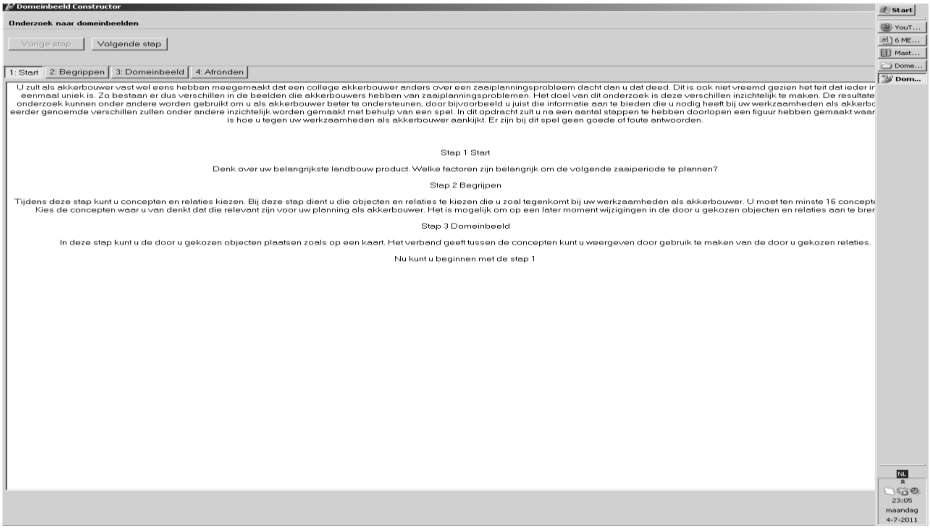


Fig. 6.2 "Start" Window

The second window (fig. 6.3) is called "Begrippen" (concepts in English). In this window, the farmer can select concepts and relationships. This window instructs the farmer to choose objects and relationships that he encounters in his work as a farmer. He must choose at least 16 concepts. It is possible at a later moment to change the chosen objects and relationships.

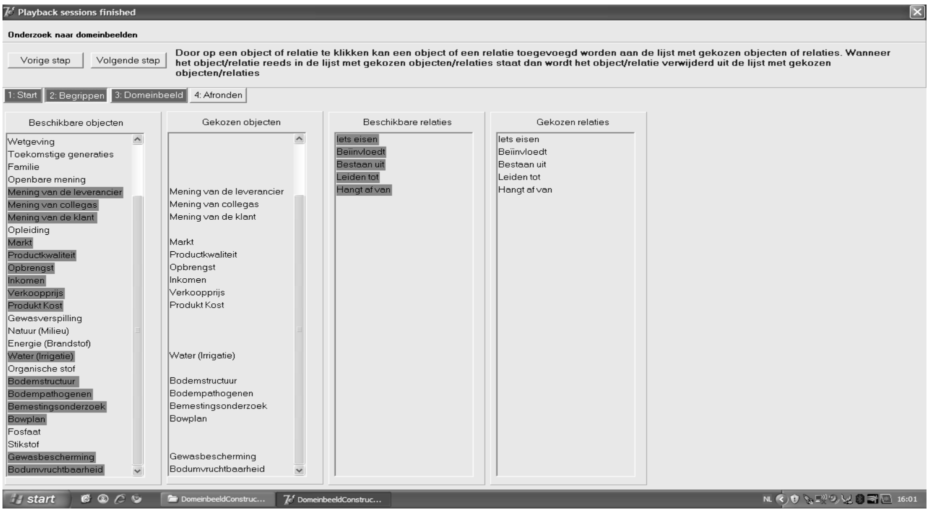


Fig. 6.3 "Concepts" window

The third window (fig. 6.4) is called "Domeinbeeld" (domain image in English). In this window, the farmer can place the selected items as shown on a map. The relationship between the production concepts can be shown by using the selected relations.

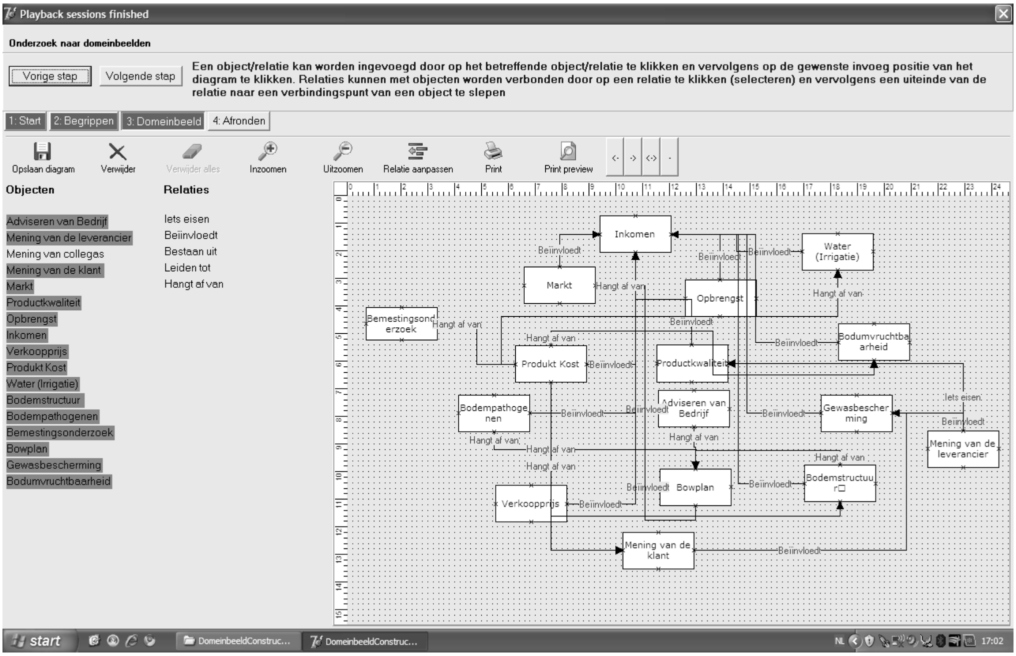


Fig. 6.4 "Domain image" window

The fourth window (fig. 6.5) is called "Afronden" (complete in English). In this window, the farmer is able to save his map on a diagram file that allows retrieving the map for further analysis.

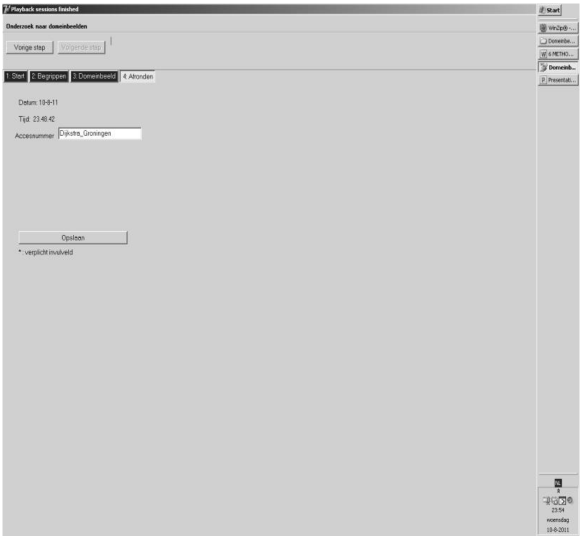


Fig. 6.5 "Complete" window

6.5.3 Assignments

After the farmer saved his cognitive map he was presented with three tasks to be solved speaking aloud (Ericson and Simon, 1993). This part was developed to gauge the systemic thinking qualities of farmers. Farmers solved three agricultural-based problems and what they have to say as they thought aloud was recorded. The farmers were told that this section was conducted to gain information about what they were thinking regarding agricultural activities. The farmers were asked to read each situation and utterance and say everything that came to their mind while they were thinking about each response. They were instructed not to wait until they finished thinking but to speak out at the same time as they were thinking. They were also instructed to say all utterance segments, even hesitations and questions (e.g., "well", "what does this mean?") and not to monitor their speech for the recording. They were told to take their time and not to worry about grammar. Along with the oral explanation, additional printed instructions in Dutch were provided and the participants were given opportunities to ask questions when the instructions were not clear. With protocol analysis, it is not always necessary to transcribe the think-aloud material in its entirety. Sometimes, for example in psychological research, everything can be relevant and researchers recommend transcribing complete protocols to discover a person's meaning. When the objective of the study is to perform a task and solve problems related to the decision making of the participants, it is possible to ignore events that the researcher considers irrelevant and not related to the particular performance under observation (Someren et al., 1994). In our study, we listened to all data. We did the transcribing and omitted those parts of the data that were not related to the focus of our study questions. Guidelines were followed in order to assure the validity of the protocols (Ericsson and Simon, 1993; Someren et al., 1994). It was stressed that the answers to the tasks were neither "right" nor "wrong"; each solution could be considered correct because it reflected a personal representation of knowledge.

Task 1

The first task was designed as a training for the farmer to get familiar with talking aloud. The task consisted in devising improvements on tractors. The task was presented as follows:

"Tractors are essential agricultural machinery. Can you come up with five improvements in tractors?"

Task 2

The second task presented the introduction of a new product to enhance soil quality. Thinking about the next generations is at the heart of the discussions regarding sustainability (chapter 2 and chapter 3). Farmers are often confronted with knowledge (chapter 4) about products, for example: new fertilizers, machinery additives, etc. Hence, a task that deals with new products is relevant to determine elements of sustainable thinking.

> "The concept of future generations often appears in the discussions regarding sustainable agriculture. This means thinking about the needs of today and the needs of the future. People have concerns about the soil quality of the land -where future farmers will work in- and how they will handle soil quality issues. However, future generations can neither deplete the soil nor contribute to the solution now. Since soil quality is linked to the discussion of future generations, there is a need to develop strategies to improve it. In the last years a product that helps to enhance the soil has been developed and studied, its name is Biochar. It is made by converting agricultural waste into a char-like material that holds carbon and makes soils more fertile, discourages deforestation, and preserves cropland diversity. Biochar makes soil better at retaining water, reduces the amount of fertilizer needed. However, it has been mostly used in small, localized areas of South America and Australia. It may increase the pH of the soil. In addition, strategies to spread biochar on a large scale are still in need to be developed.
>
> - Shall you take into account future generations in the way you manage your farm?
> - Shall you accept to add Biochar to your soil?"

Task 3

The third task presented the farmer with the request of a fellow farmer to give an advice regarding pest control. Reducing or eliminating the use of substances that deteriorate the environment is one of the challenges that farmers face. Therefore, the way that farmers handle with this issue is relevant to identify elements of sustainable thinking.

> “Recently, you have received the following letter from a fellow farmer:
>
> My land has been suitable for raising potatoes and my grandfather with much forethought started to grow potatoes around 60 years ago. Since the last 40 years, chemicals have entered the scene in order to help to increase production yields and to fight soil-borne diseases. The use of those chemicals allowed increasing the yield and a relatively good nematode control. However, for the last ten years during which I was in charge of the farm, I have heard that the use of chemicals may have an adverse effect to the environment and to human health. Lately, I have been wondering as to whether I should stop using these products in my field. I am not sure of the success of the non-chemical methods in order to increase yield and those of pest control, so, that would mean putting at stake my main source of income.
>
> - Please indicate, how can your fellow farmer solve this situation?
> - Please indicate, what methods do you use to control diseases and pests?”

We subsequently perform the scoring of each one of the assignments. In the first place, we do the transcription of all the assignments. Afterwards, we do the encoding by dividing the written protocol into segments, each corresponding to one sentence, clause, or even word. We encoded the segments inductively using the information contained in them. We began the coding of our study during the transcription process. We wrote each sentence or clause on a separate line. After that, we put all the typewritten data into qualitative data analysis software, NVivo9 (QSR International, 2011). We continued the coding so that each text line was read, and according to the protocol analysis, we coded first- and second-level verbalizations either as a decision or as information used in solving-task. All together, we have defined five different systemic qualities to be studied (section 4.5.1): (a) Integration (b) Time Horizon (c) Interconnections (d) Feedback (e) Cooperation. In order to illustrate our findings better we provide one characterization. We profile the protocols from each farmer with respect to the systemic thinking qualities aforementioned. This characterization allows comparing the different farmers.

6.5.4 Open Interview

The last part of the instrument consisted of open questions about attendance to educational programs where the subject of sustainable agriculture was covered, participation in projects that involved sustainable practices, and personal initiatives in order to protect/enhance wildlife habitat, water/soil quality. For this part, we used qualitative content analysis, which is one of the procedures for analyzing textual material (Bauer and Gaskell, 2000; Flick 2006). We do not expect extensive answers in this part since it is the last part of the instrument and the interviewees might be tired after almost one hour of given answer to the previous parts.

6.6 Data Processing and Analysis

The data obtained from the first part of the instrument was tabulated and a descriptive analysis was carried out. An analysis was accomplished with the cognitive maps thus obtained. According to Dunn et al. (1986), cognitive maps can be analyzed on two dimensions: the content differences (differences in concepts contained in two or more cognitive maps) and structural differences (corresponding to varying degrees of complexity of the map structure. The number of words in each category was counted. The quantity and variety of words used by farmers were also observed. With this, a schematic representation of the each cognitive map was made. The links (arrows) that connect the concepts belonging to the different TBL categories were also analyzed. For each map, we counted the total number of links and the number of links that were drawn between concepts. This, as discussed in section 5.4.4 will provide insight into the degree of complexity of the map. The heads of a map are those concepts that are represented by nodes that have only arrows going inside (no arrows going outside). They are goals expressed in terms of effects. Tails are those concepts represented by nodes that have only arrows going outside (no arrows go inside). They are concepts that explain the cause of a current situation. In order to study the hierarchical order and structure among ideas we analyzed the map's configurations. We were interested in the feedback relations. A feedback relationship is a group of concepts that form closed paths.

We subsequently performed the analysis of the protocols. Verbal reports are divided into three different levels of verbalization. Level 1 or talking aloud, level 2 or thinking aloud and level 3 which includes introspective reports (Ericsson and Simon, 1993). Traditionally, researchers consider only the first- and second-level verbalizations as reliable because these levels are assumed to reveal the content of working memory (Sasaki, 2003). At the third level, participants further process verbalizations and pay attention to additional information obtained before verbalization. The thinking processes are no longer essential for the immediate performance or the attention of the participant is no longer focused on the task under observation (Boren and

Ramey, 2000). We also excluded the third-level verbalizations in our own study. We began coding of our study during the transcription process. We wrote each sentence or clause on a separate line. After that, we put all the typewritten data into qualitative data analysis software, NVivo9 (QSR International, 2010). We continued the coding so that each text line was read, and according to the protocol analysis, we coded first- and second-level verbalizations either as a decision or as information used in solving-task. All together, we have defined five different systemic qualities to be studied (section 4.5.1): (a) Holism (b) Time Horizon (c) Interconnections (d) Feedback (e) Cooperation. In order to illustrate our findings better we provide one characterization. We profile the protocols from each farmer with respect to the systemic thinking qualities aforementioned. This characterization allows comparing the different farmers.

6.7 Instrument Validity

Validity refers to the extent to which a measurement is well founded and it corresponds accurately to the real world (Miles and Huberman, 1994). The instrument is valid for a specific purpose with a specific group of people. Since our instrument is built on different knowledge elicitation techniques, we discuss the validity of every element of the instrument.

6.7.1 Cognitive Mapping Validity

Techniques for eliciting and representing cognitive structure are based upon the assumption that 'similarity data' - describing the relationships between a set of stimuli -provides an index of the organization of these concepts in human memory (Fillenbaum and Rapoport, 1971). The validity of the representations generated by cognitive maps can be compromised by several methodological limitations. In order to overcome the possible methodological issues associated to the cognitive mapping technique we do the following: 1) a theoretical framework for characterizing the agricultural domain is devised to provide an explicit rationale for the selection of concepts used, 2) a relatively simple, rapid, and unconstrained elicitation procedure through a domain constructor program is employed, leaving subjects free to determine their own criteria of correspondence and 3) the cognitive map procedure is combined with verbal protocols and direct observation, to provide a fuller picture of cognitive structure and facilitate interpretation.

6.7.2 Protocol Analysis Validity

Participants, faced with the task of constant verbalization, are typically "coached" on how to deliver a think-aloud protocol (Ericsson and Simon, 1993). This often takes the form of a warm-up exercise where the participant and experimenter practice thinking aloud. In order to assure the validity of the protocol analysis in our study we present a warming-up task to the farmers. We also follow the suggestions given by Nielsen (1993) which exhort the interviewer to intervene as little as possible, yet directing the flow and direction of the interview to allow the interviewee to express their thoughts. We prompt when the participant ceases to verbalize with short statements such as "please keep talking." Kuniavsky (2003) lays out the guidelines for "non-directed" interviewing: questions should be concentrated on immediate experience, nonjudgmental, focused on a single topic, open-ended, and non-binary (e.g. yes-no, true-false). Problems with working memory and synchronization can be recognized by complaints by the subject and interrupted verbalizations (Someren et al., 1994). If these phenomena take place during the think aloud method it is recommended to change the method, the task or the subjects. In our study the farmers did not complain about the assignments. The farmers did not interrupt the verbalizations either.

6.7.3 Open Interview Validity

We completed our study with a series of open questions. Interviewees have a complex stock of knowledge about the domain under study, sustainable agriculture. This knowledge includes assumptions that are explicit and immediate, which interviewees are more likely to express spontaneously in an openly designed interview situation than in a standardized interview or questionnaire. (Flick, 2006; Groeben, 1990). In order to guarantee the validity of the questions we asked, we follow the directives from Wolcott (1990) during the interview process:

- Elaborate an interview guide;
- Pretest the interview guide;
- Avoid the alteration of the interview guide structure during the interviews;
- Refrain from talking in the field but rather listening as much as possible;
- Produce notes that are exact as possible;
- Transcribe the interview as soon as possible;
- Use a unique format to transcript the interview;
- Validate the interview with the interviewee

6.8 Conclusion

This chapter described the empirical design of this research. Two studies were carried out. A pilot study realized to collect data regarding farmers' knowledge of sustainability. After the pilot study, a full study was conducted. During the full study, an instrument was developed in order to elicit farmers' knowledge structures. A distinction between the content and process of knowledge structure was made in the research questions described in section 5.3. Therefore, the empirical testing was different for both domains. Cognitive mapping was adopted to elicit how farmers structure his knowledge. Protocol Analysis was employed to understand how a farmer reasons with his knowledge. As explained in this chapter, guidelines were followed to ensure the credibility and consistency of the instrument. The presentation and discussion of the empirical results will be discussed in the following chapter.

7 RESULTS

7.1 Introduction

In section 5.5, hypotheses were derived from the conceptual model presented in section 5.4. We discuss the results in the following order. First, in section 7.2, we discuss the independent variables at a descriptive level. We provide an overview of the farmers that participated in our study. In section 7.3, we subject the cognitive maps obtained to the analyses explained in section 6.5. In section 7.4, the verbal reports obtained during the problem-solving task of the instrument are analyzed in order to get insights in the reasoning patterns of the farmers. The results of the hypotheses testing are presented in section 7.5. We then subject data to a secondary analysis in section 7.6. The final section of the chapter (7.7) summarizes the main findings.

7.2 Farmer Characteristics Overview

As summarized in table 7.1 the farmers that participated are –on average- middle aged adults. These farmers have on average 23.6 years of experience. This indicates that the farmers have spent long periods in the farming practice. The average size of the farms is 98 ha which is almost four times bigger than the average size of a farm in the Netherlands, 26 ha in 2010 (Agricultural Economics Research Institute, 2011). Closer examination of the farm scale (number of ha) indicates that 10 percent of the sample is equal to or bigger than 200 ha. Excluding these farms the average size is 81.12 ha. This suggests that the sample average does not correspond to the national average and that therefore the sample might not be fully representative in this aspect. Also the average production of potatoes is higher than the Dutch average 46.2 ton/ha (FAOSTAT, 2011).

Table 7.1 Demographic aspects of the farmers

	N	Minimum	Maximum	Mean	Std. Deviation
Age	80	27	69	49,30	10,145
Years of Experience	80	1	45	23.66	11.010
Area (ha)	80	8	350	98.08	64.571
Potato Yield (Ton/ha)	80	30	120	59.09	19.980
Valid N (listwise)	80				

Table 7.2 shows the educational level of the interviewees. Most of the interviewees had a middle level education, which is a vocational education that prepares people for jobs that are based on manual or practical activities. In these case most of them attended an agricultural school. It is interesting to note that one third of the participants in this study had higher education. This means that the sample is not representative in educational aspects. Education is particularly relevant for the farmer to facilitate the recognition of a problem and the awareness of potential solutions (Prager and Posthumus, 2010).

Table 7.2 Education Level

	Frequency	Percent	Valid Percent	Cumulative Percent
University	4	5.0	5.0	5.0
Polytechnic	23	28.8	28.8	33.8
Middle level Applied Education	52	65.0	65.0	98.8
High school	1	1.3	1.3	100.0
Total	80	100.0	100.0	

Table 7.3 shows that most of the farmers grow more than 2 crops; this is what an average Dutch farmer grows (FAOSTAT, 2011).

Table 7.3 Crop Diversification

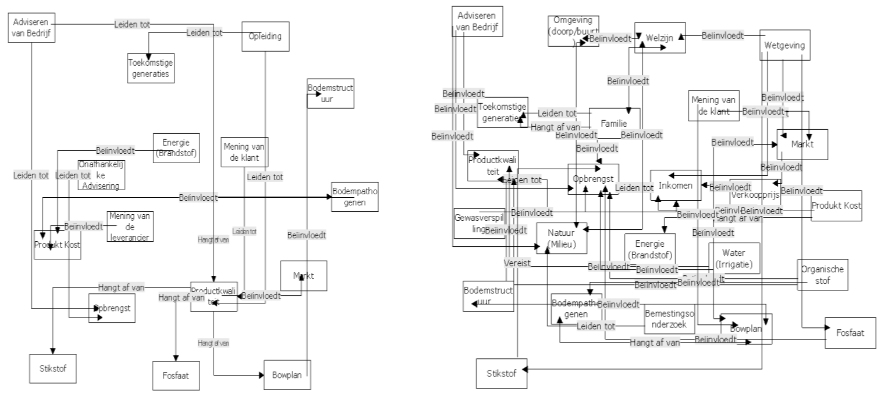
	Frequency	Percent	Valid Percent	Cumulative Percent
5 or more crops	25	31.3	31.3	31.3
3-4 Crops	47	58.8	58.8	90.0
1-2 Crops	8	10.0	10.0	100.0
Total	80	100.0	100.0	

The Dutch government has adopted the CAP's approach of promoting economic diversification, in order to promote the vitality of the countryside. They aim at producing high quality products against relatively low prices. Yet, the sector faces some dilemmas: internationally price competition is strong and nationally farmers have to find a new balance between the different aspects of sustainability: Profit, People and Planet (SER, 2008). Almost half of the interviewees have another agricultural extra activity (i.e., energy production, advising, and tourism). This means that even if farmers' primary occupation is food production, agriculture is starting to involve much more than the production of crops and animals for food consumption. The complexity of the challenges faced by their profession requires farmers to play many roles.

7.3 Cognitive Mapping

7.3.1 Counting of concepts by TBL category

The cognitive mapping exercise yielded 80 cognitive maps displaying participants' conceptual meanings of their knowledge of sustainable agriculture. Participants' cognitive maps sorted into a variety of structures such as exemplified in figure 7.1. Figure 7.1 (a) shows a map drawn with the number of concepts that was chosen more frequently (16). Figure 7.1 (b) shows the map with the maximum number of concepts used (24).



(a) (b)

Fig. 7.1 Cognitive maps "built" by two participants (a) average number of concepts, (b) maximum number of concepts

We asked the interviewees to include at least 16 (of the maximum of 32) concepts in their maps. Maps varied in their clarity with some able to be more easily interpreted than others. The three themes from the Triple Bottom Line (TBL) approach allowed us to conceptualize the data while still capturing its diversity. We developed a list of 32 concepts expected to be integrated in the mental models of the farmers (see section 6.5.2). These concepts refer to concepts of the 3P's in the Triple Bottom Line Approach (People, Profit, and Planet). People had 13 concepts, Profit had 6 concepts, and Planet had 13 concepts. The consistency of these concepts was determined and defined by a group of experts within the RuG and BLGG. Only four persons chose 20 or more concepts. The interviewees emphasized the category of Planet. One of the farmers selected only 15 concepts arguing that there were no more concepts relevant to him. The number of concepts that was chosen more frequently was 16. Table 7.4 provides a summary of the total results.

Table 7.4 Outlook from the concepts mentioned in the cognitive maps

	Average number of concepts used to draw a cognitive map	SD	Maximum number of concepts used to draw a cognitive map	Minimum number of concepts used to draw a cognitive map
Total	17	1.61	24	15
Planet	6	1.25	9	4
People	5	1.17	7	3
Profit	5	1.03	6	3

Figure 7.2 shows the concepts that were mostly used by the farmers while building the cognitive maps regarding the theme of Planet. The concept of soil structure was selected by -94% of farmers, followed by sowing plan with 85% and fertilizer research with 70%. Soil structure and sowing plan are concepts that the farmer can analyze himself. Farmers know the physical condition of their land and they know what they want to grow. It is also interesting to note that the concepts that received more than 60 % of the mentionings are concrete oriented (soil structure, sowing plan, fertilizer research and organic matter) whereas the concepts that received less than 40% of the mentionings are more abstract (nature, water, crop waste and energy).

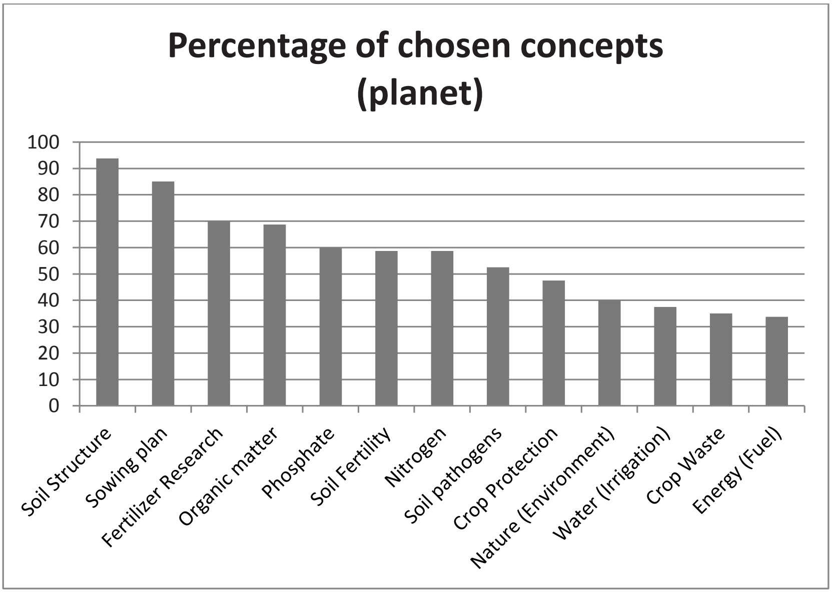


Fig. 7.2 Percentage of total mentions for the theme of planet

Figure 7.3 shows the percentage of total chosen concepts for the theme of Profit. The six concepts included in this theme have high percentages of mentioning: all above 75% (dashed line). The profitability of the farm is an important aspect when it comes to plan the next growing season.

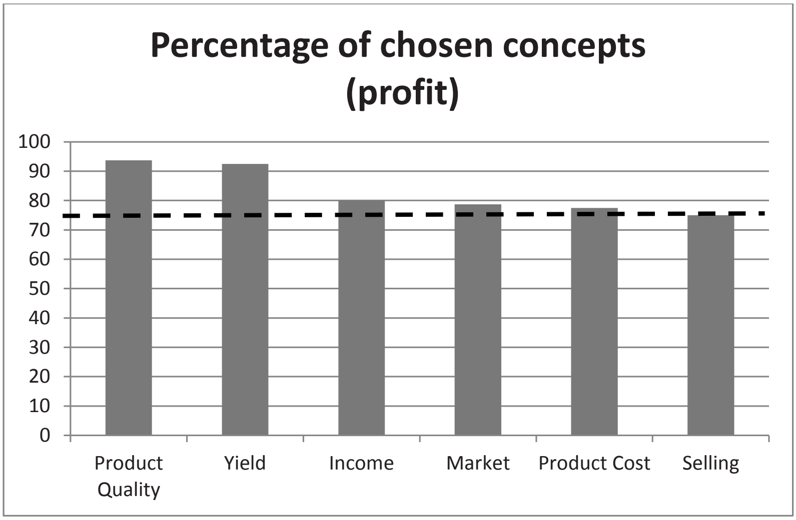


Fig. 7.3 Percentage of total chosen concepts for the theme Profit

Regarding the theme of People, customer opinion was the most used concept with 65% of mentionings (figure 7.4). This shows a contrast with the other two P's (Planet and Profit) where concepts were mentioned with higher frequencies. In our discussion of agricultural sustainability (chapter 3), we argued that the social component of sustainability has been left aside in the sustainability debates. We therefore expected that concepts included in the People theme would have less mentionings than Planet and Profit. It may also suggest that there is a lack of information about the social aspects of sustainable agriculture. We can also note that the concepts with mentionings above 50 % involve expert opinion (independent and business advice and legislation) whereas the concepts that received less than 20% of the mentionings are related to the close network of the farmer (e.g., family, colleagues and local environment).

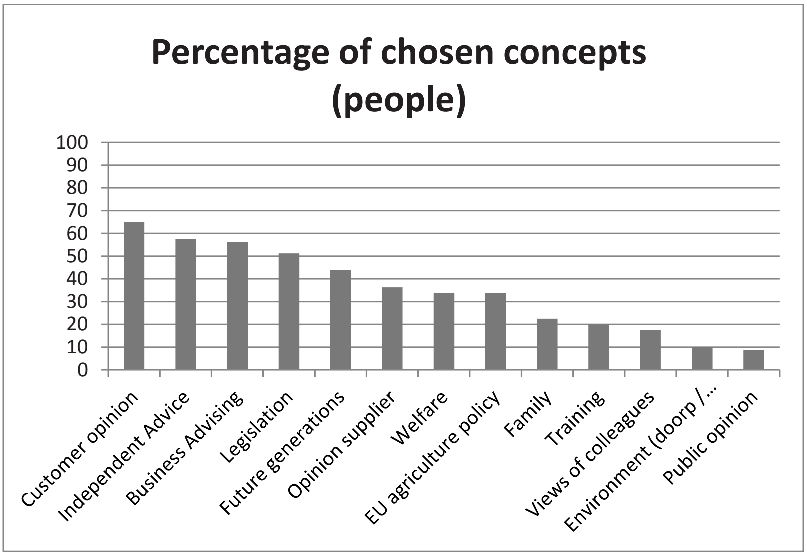


Fig. 7.4 Percentage of total chosen concepts for the theme people

Earlier on this study some participants referred often that they had participated in a special project. We noticed that 17 out of 80 farmers participated in the same project, a project called "Veldleeuwerik." This is a project where farmers interested in sustainable practices join on a voluntary basis. This project incorporates concepts from the TBL in their discussion (Stichting Veldleeuwerik, 2011). Hence, we considered that this characteristic could give some interesting (dis) similarities in the knowledge aspects farmers hold. Table 7.5 shows the concepts used in the cognitive maps of both groups (non- Veldleeuwerik and Veldleeuwerik). Both groups presented strong economic emphasis (Profit) since both frequently selected the 6 concepts that correspond to this theme. Regardless of whether farmers participated or not in the Veldleeuwerik project, the "top 4 concepts," that is the concepts with more mentionings were soil structure, product quality, yield and sowing plan. There were also two concepts from the Planet theme and two concepts from the Profit theme. The least five mentioned concepts for both groups correspond to the People theme: family, training, views of colleagues, environment, and public opinion. Interesting is that public opinion appears on the last place. It seems that whereas there is a growing concern among civil society regarding the impacts of agriculture (European Commission, 2007), for some farmers this opinion is not relevant. All the participants of the Veldleeuwerik project mentioned the concept of soil fertility whereas less than the half of the non-participants mentioned it. We did not expect such a big difference since in the two groups since the soil is considered to be the most important asset within agriculture in both groups for farmers in the general sense (see also 2.6.1).

Table 7.5 Percentage of concepts used in the cognitive maps (non- Veldleeuwerik vs. Veldleeuwerik participants).

CONCEPTS	**Total (%)**	**Non-Veldleeuwerik Group (%)**	**Veldleeuwerik Group (%)**	**Triple Bottom Line Approach Themes**		
	(n= 80)	(n=63)	(n=17)	**Planet**	**Profit**	**People**
Soil Structure	94	94	94	X		
Product Quality	94	94	94		X	
Yield	93	92	94		X	
Sowing plan	85	84	88	X		
Income	80	76	94		X	
Market	79	78	82		X	
Product Cost	78	79	71		X	
Selling	75	81	53		X	
Fertilizer Research	70	73	59	X		
Organic matter	69	70	65	X		
Customer opinion	65	68	53			X
Phosphate	60	60	59	X		
Nitrogen	59	60	53	X		
Soil Fertility	59	48	100	X		
Independent Advice	58	62	41			X
Business Advising	56	67	18			
Soil pathogens	53	51	59	X		X
Legislation	51	56	35			
Crop Protection	48	40	76	X		X
Future generations	44	44	41			X
Nature (Environment)	40	35	59	X		
Water (Irrigation)	38	30	65	X		
Opinion supplier	36	41	18			X
Crop Waste	35	32	47	X		
EU agriculture policy	34	37	24			X
Welfare	34	29	53			X
Energy (Fuel)	34	25	65	X		
Family	*23*	*21*	*29*			*X*
Training	*20*	*24*	*6*			*X*
Views of colleagues	*18*	*19*	*12*			*X*
Environment (neighborhood)	*10*	*10*	*12*			*X*
Public opinion	*9*	*6*	*18*			*X*

On average Veldleeuwerik and non-Veldleeuwerik farmers differ in a positive way in favor of Veldleeuwerik concerning the number of Planet concepts (t=-3.75, p=0.000), meaning that participants of the project choose 9 concepts on average and the non-participants 7. Regarding the number of Profit concepts there is also a positive difference (t=2.553, p=0.013). Veldleeuwerik farmers choose 3.59 concepts on average and non-veldleeuwerijk chose 4.88 concepts on average. However, there is not a difference for the number of People concepts used (t= 0.406, p=0.686). The average concepts used by participants of the project were 4.83 and 5 for non-participants. In summary, the construction of the cognitive maps emphasized the Planet concepts in the case of Veldleeuwerik farmers and for Profit concepts in the case of non-veldleeuwerik.

7.3.2 Map Densities

Map density was defined in section 5.4.4. It is used as a proxy for the complexity of thinking. In this study, map density is determined by the ratio of number of relations used in a map to the maximum number of relations in a map with 32 concepts. We would like to explore whether there are any differences among the participants of our study regarding the complexity of their thinking. Hence, we tested differences among map densities. In order to test this, the data should be normal. Through normality tests (Kolmorogov-Smirnov) it was found that the distribution of the map density was non-normal (D(80)=0.156, p=0.00). An inverse transformation was performed for the normalization of this variable (D(80)=0.074, p=0.200). Table 7.6 provides some examples of calculated map densities. In the appendix section, a table with the calculated map densities for all the farmers is presented (Appendix I).

Table 7.6 Calculation of Map Densities

Interviewee	Selected Concepts	Relations used in the map	Map Density	Inverse Transformation (1/map density)
1	16	16	0.0161	62.1118
2	16	22	0.0222	45.0450
3	19	16	0.0161	61.1118
4	16	26	0.0262	38.1679
5	16	13	0.0131	76.3358
6	18	32	0.0323	30.9597
7	16	20	0.0202	49.5049
8	21	25	0.0252	39.0682
9	18	11	0.0111	90.0900
10	16	11	0.0111	90.0900

We already discussed the participation of farmers in the Veldleeuwerik project. The similarity in the average value of the transformed map densities of both groups (non-veldleeuwerik and veldleeuwerik) were analyzed by an independent samples t-test, which reveals that there is a difference ($t= 2.167$, $p = 0.033$). The farmers that participated in the Veldleeuwerik project have an average map density of 0.0207 versus an average of 0.0172 of the non-veldleeuwerik farmers. This suggests that farmers that participated in the project use more concepts and therefore think more complex about sustainability.

7.3.3 Clusters

A cluster is a group of relatively homogeneous observations. It is useful to examine the similarities or distances to locate similar groupings of observations (that is, larger than just one pair). The term “cluster analysis” is used to describe a large number of techniques, which attempt to determine whether or not a data set contains distinct groups and, if so, to determine these groups. Cluster analysis aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. Legendre & Legendre (1998) provide a recent, thorough, discussion about cluster analysis.

We carried out an agglomerative hierarchical cluster analysis since the number of clusters that will emerge in the analysis is unknown and the data set is small (Hair et al., 2005). Ward’s method was used as a clustering algorithm applying squared Euclidean Distance as the distance or similarity measure. This helps to determine the optimum number of clusters we should work with. As a general process, clustering can be summarized as follows: The distance is calculated between all initial clusters. Initial clusters are made up of individual cases. Then the two most similar clusters are fused and distances recalculated. This is repeated until all cases are eventually in one cluster.

The results of the cluster analysis are shown by a dendrogram (figure 7.5), which lists all samples and indicates at what level of similarity or distance clusters join. The dendogram is a visual representation of the steps in a hierarchical solution. Since the number of clusters is not known, the dendrogram provides an indication of the appropriate number of clusters to keep. The dendrogram is formed by applying the agglomerative method to the cognitive maps of the 80 interviewees having the chosen concepts for each theme of the Triple Bottom Line approach (TBL) per individual cognitive map as variables. The horizontal axis shows the dissimilarity measure on the basis of squared Euclidean distances. The vertical axis orders the farmers identified by serial number and label. While reading the dendrogram, we determined -by drawing a dashed line- at what stage the distances between clusters that are combined begins to be large.

Determining the number of clusters is often a primary goal. Typically, one looks for natural groupings by long stems. By doing this, we can identify 4 clusters.

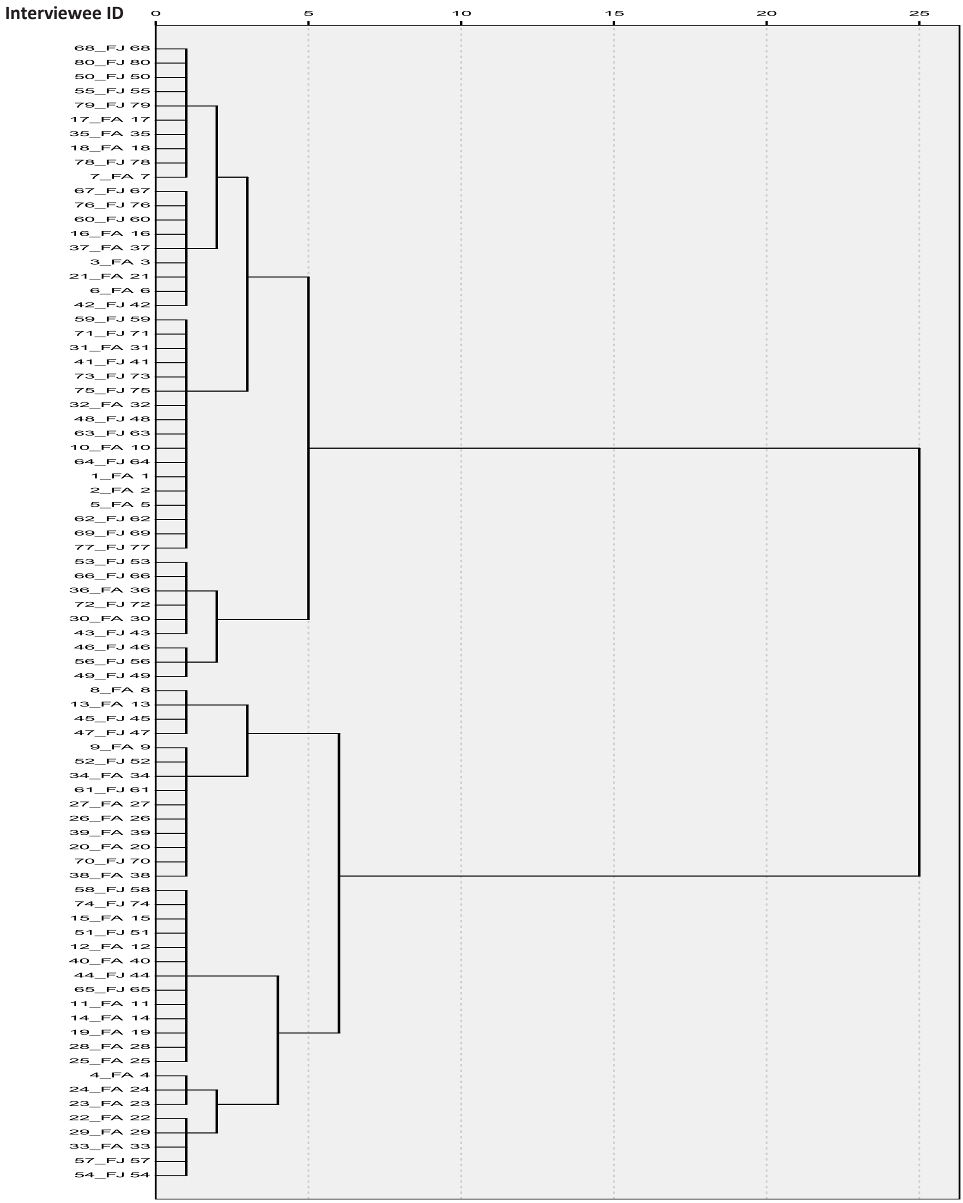


Fig. 7.5 Dendrogram for the 80 farmers

Once we identified four cluster solutions we rerun the analysis with the selected number of clusters. This enables us to draw a boxplot where the boxes represent each of the themes of TBL (Planet, People, and Profit). Figure 7.6 shows what the relationship is between the TBL themes selected in the different cognitive maps for the four cluster solution. It appears that the farmers included in cluster number 1 keep a balance among the themes from the TBL approach within their cognitive maps. Farmers belonging to cluster 2 are Planet oriented. These farmers used less Profit concepts than the other three clusters. For example, farmer 54_FJ did not mention any concept regarding Profit. Cluster 3 suggests that the farmers are also Planet oriented. They include a similar number of concepts of People and Profit in their cognitive maps. Cluster 4 indicates that these farmers are Profit oriented. They included a similar number of Planet and People concepts but one farmer (49_FJ) used only 2 People concepts.

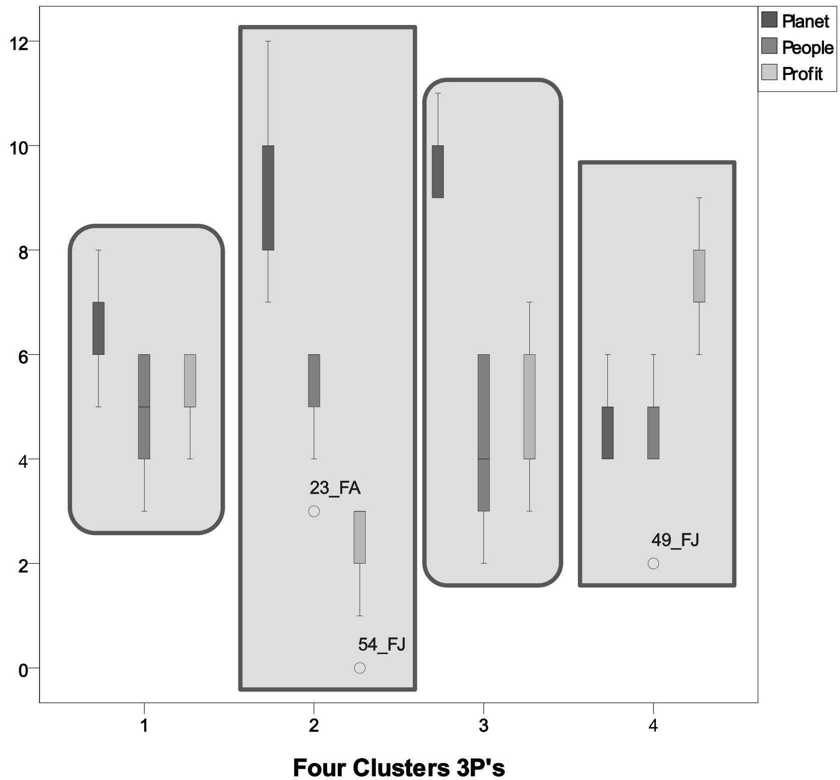


Figure 7. 6 Box Plot for the four cluster solutions

Table 7.7 presents the functions that linearly describe the different clusters found, which were determined using a discriminant function analysis using Planet, People and Profit as clustering variables and the found clusters as inputs.

Table 7.7 Discriminant functions

Cluster	**Constant**	**Planet**	**People**	**Profit**
Cluster 1	-69.701	8.213	8.493	8.021
Cluster 2	-76.278	10.204	9.113	4.849
Cluster 3	-91.311	11.038	8.581	7.721
Cluster 4	-76.370	7.054	7.956	10.525

We also wanted to estimate the stability of the clusters through a clustering function obtained by a discriminant function analysis. Stability means that cluster assignation should not disappear easily if the data set is changed in a non-essential manner (Hennig, 2006). For this, first, we divided the sample in two halves (half A and half B). Secondly, a cluster analysis was performed with the data from half A. In third place, the functions that linearly describe the clusters from half A were determined (table 7.8).

Table 7.8 Discriminant functions

Cluster	**Constant**	**Planet**	**People**	**Profit**
Cluster 1	-79.709	11.927	8.373	8.747
Cluster 2	-101.893	15.655	7.222	9.665
Cluster 3	-132.211	19.466	6.790	9.323
Cluster 4	-97.605	15.386	8.680	7.164

The fourth step was to do a cluster analysis with the data from half B. Additionally (fifth step), with the clustering function obtained in the third step, clusters to the data from half B were assigned. The final step was to compare both clusters for half B (those obtained from the cluster analysis versus those based on the discriminant function analysis). A chi-squared test showed that there is no difference (χ^2=1,800 , df=3 , p= 0.615) between the clusters obtained from the cluster analysis and the clusters assigned through the discriminant analysis. We conclude that the cluster analysis is stable.

7.3.4 Relationships

In using cluster analysis, there is the implicit assumption that the similarities or distances among the cases reflect single underlying dimension. It is possible, however, that there are multiple "aspects" or "dimensions" underlying the observed similarities of cases. The purpose of multidimensional scaling (MDS) is to provide a visual representation of the pattern of proximities (i.e., similarities or distances) among a set of objects. The input to MDS is a square, symmetric matrix indicating relationships among a set of items.

The cognitive maps as realized in our study are understood as distance. The MDS technique allows building a multi-dimensional space in which the nodes of the cognitive map (i.e., the concepts) are positioned. MDS subsequently connects the nodes to one of the dimensions in the space, based on the linkages that exist between the concepts. First, the cognitive maps were transformed into the appropriate shape. For MDS to be used, matrices derived from each cognitive map were built. These matrices included the 32 concepts that have been available to the farmers during the map productions. Therefore we built 80 -(32x32) matrices. The idea of the MDS analysis is that the dimensions of the space should reflect the aspects of sustainability responsible for the projected proximities.

MDS finds a set of vectors in a multidimensional space such that the matrix of Euclidean distances between them corresponds as closely as possible to some function of the input matrix according to a criterion function called stress. From a mathematical standpoint, non-zero stress values occur for only one reason: insufficient dimensionality. That is, for any given dataset, it may be impossible to perfectly represent the input data in two or another small number of dimensions. On the other hand, any dataset can be perfectly represented using $n-1$ dimensions, where n is the number of items scaled. As the number of dimensions used goes up, the stress must either come down or stay the same. It can never go up. It is not necessary that an MDS map has 0 stress in order to be useful. A certain amount of distortion is tolerable (Quinn and Burgman, 2011). Table 7.9 shows the compatibility of the configuration distances to the original ones on the basis of stress values.

Table 7.9 Compatibility of configuration distances in MDS (Quinn and Burgmann, 2011)

Stress Value	
>0.20	Incompatible presentation
0.1 -< 0.20	Low compatibility
0.05 -< 0.1	Good compatibility
0.025 -< 0.05	Perfect compatibility
0.00 - < 0.025	Full compatibility

There are two things to look for in interpreting an MDS picture: clusters and dimensions. For example, in an MDS map of perceived similarities among sustainability concepts, it can be expected (among farmers that do not participate on sustainable projects) that the concepts included in the Profit category are all very near one another, forming a cluster. Similarly, the concepts included in Planet and People form a cluster among farmers that have attended sustainable projects.

The MDS analysis for the 80 participants in the study was carried out bi-dimensionally (fig. 7.7). It was iterated up to the value where the stress improvement was less than 0.001. For MDS solutions, the dimensional solutions giving stress value near 0 are desirable. The stress, which is used for determining the appropriateness between the configuration distances and estimated distances, is 0.09919. The horizontal dimension (dimension 1) can be interpreted in terms of the Planet discussion (shaded rectangle). Within quadrant III we find concepts from both the managerial orientation (People) and Planet. Quadrant IV only includes Planet concepts. The vertical dimension (dimension 2) corresponds to a preference for managerial concepts. This is illustrated by the concepts contained in the shaded ovals (opinion from colleagues and customers, EU agricultural policy, legislation, product cost, product quality, yield). Quadrant II contains only managerial concepts. In quadrant I, market, selling price and income are located further away from the rest (shaded circle). This indicates that, in general, the interviewees may have a special consideration for these three concepts while taking decisions about their enterprise. This means that the Profit concepts might be more important than Planet or People concepts while taking decisions about farming practices.

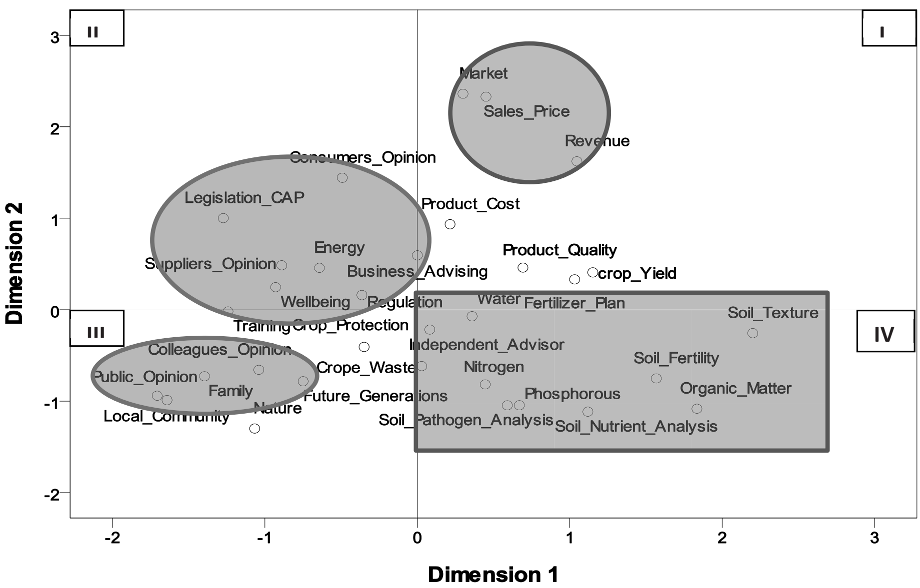


Fig. 7.7 MDS map for the farmers (all concepts included)

The MDS analysis for farmers that participated in the Veldleeuwerijk project was carried out bi-dimensionally. The stress is 0.07819. Figure 7.8 shows the positions of the 32 items in a two dimensional space. It appears that the quadrants I and IV can be interpreted in terms of the social dimension (People) of sustainability since all the concepts that are part of the People dimension group here (shaded rectangle). In addition, dimension 1 can be interpreted as a dimension that concerns interaction. Interaction is defined as a way of framing the relationship between farmers.

The concepts included within the rectangle also suggest that the more the concepts shift in the horizontal axis the more concepts related to interaction with other farmers are found (colleagues' opinion, independent advisor, suppliers' opinion, and business advising). Dimension 2 indicates the environmental dimension. The shaded circles show the Planet concepts cluster in quadrant II followed by quadrant III. This supports the findings shown in section 7.3.1 that indicate that Veldleeuwerik farmers chose on average more Planet concepts. The concepts of income, selling price and market do not group. This indicates that these concepts are not as relevant for Veldleeuwerik as for non-Veldleeuwerik farmers.

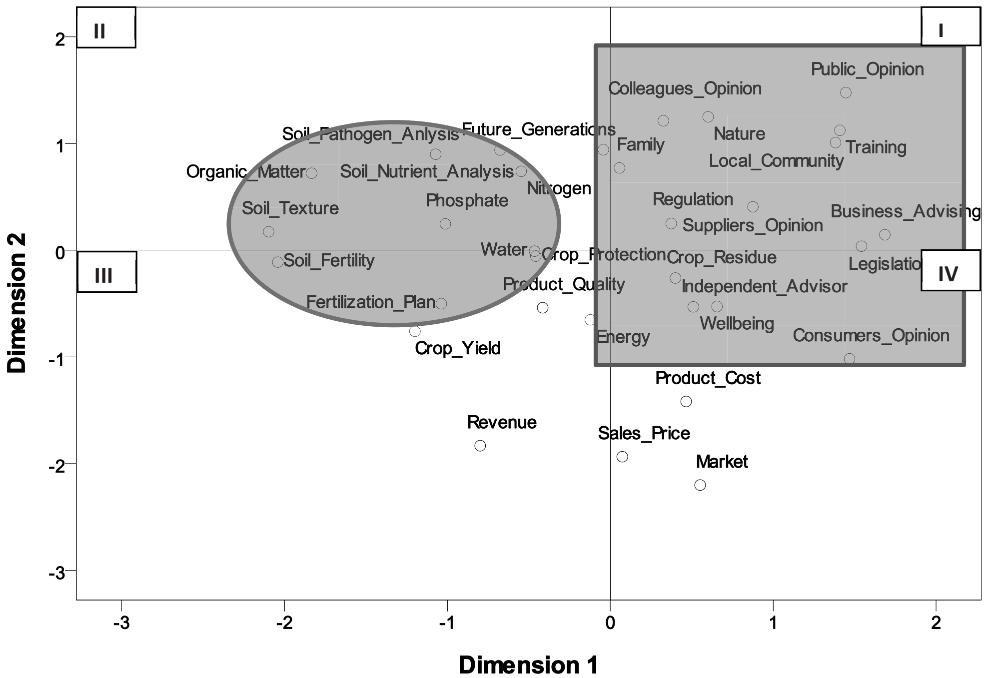


Fig. 7.8 MDS map for the Veeldleeuwerik participants (all concepts included).

The MDS analysis for farmers that did not participate in the Veldleeuwerijk project was also carried out bi-dimensionally. The stress is 0.08716. Figure 7.9 shows that the concepts of market, sell price and income cluster together (shaded circle). They appear to be separated from the rest of the concepts. This may suggest that this group of interviewees include these concepts in their knowledge of the domain. Regarding the positions of the 32 items in the two dimensional space, it appears that the horizontal dimension can be interpreted in terms of the complexity (shaded rectangles). Concepts in quadrant III (soil nutrient analysis, phosphorous, fertilization plan, soil fertility, soil texture) can be seen as more concrete. Concepts in quadrants I and IV are of a more abstract nature (well-being, family, nature, future generations, EU agricultural policy, opinion from customer and supplier). In addition, the vertical dimension separates the items into the Planet dimension since all these concepts (except from energy) appear in the quadrants III and IV (shaded oval).

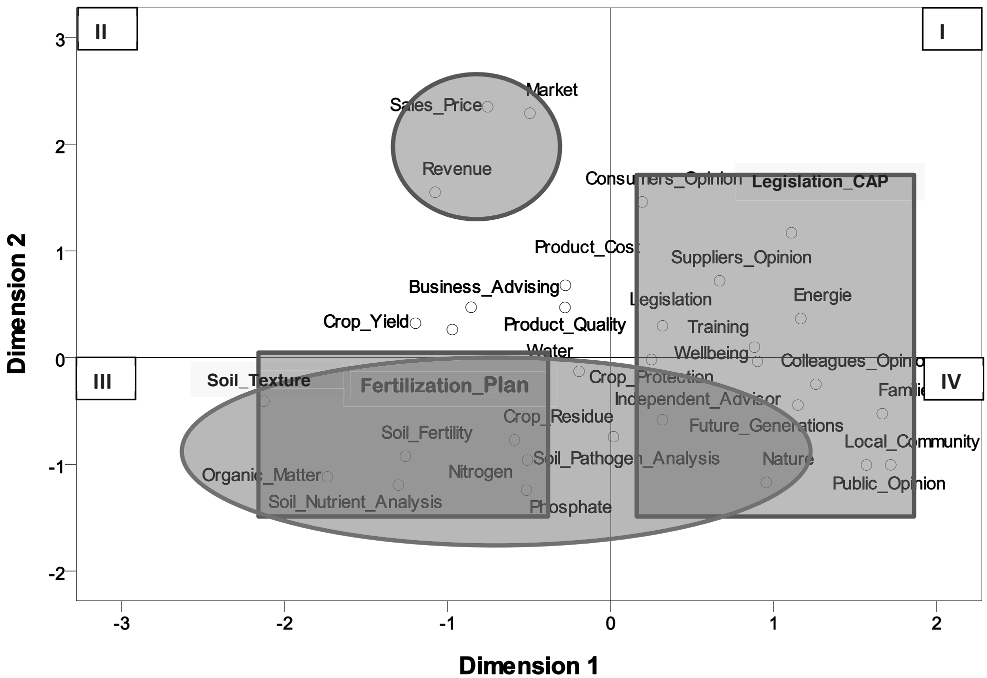


Fig. 7.9 MDS map for Non-Veldleeuwerik participants (all concepts included)

We identified the 10 concepts that were most included in the cognitive maps. A MDS analysis for all farmers, with a cut-off of ten concepts, was carried out bi-dimensionally. The stress is 0.07442. Figure 7.10 shows the positions of the ten items in a two dimensional space.

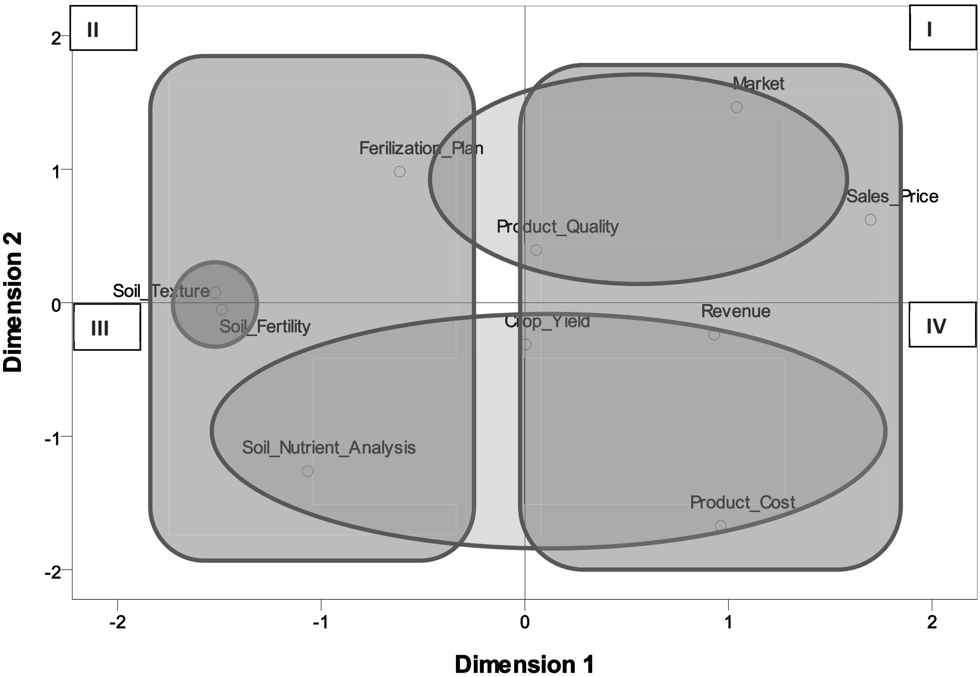


Fig. 7.10 MDS map for the whole farmers (cut-off ten concepts).

Dimension 2 can be described in terms of abstract and concrete (shaded ovals). Concrete (soil nutrient analysis, soil fertility, yield, product cost, and revenue) refers to concepts that are described by a fixed number, quadrants III and IV. Abstract (product quality and market) refers to ideas or something that has to be planned, see quadrants I and II. The horizontal dimension (dimension 1) suggests the sustainability discussion (shaded rectangles). We see that in quadrants II and III only Planet concepts are found. The concepts of soil texture and soil fertility are closely related (shaded circle). On the positive side (quadrants I and IV), the six concepts included in Profit are included. When a cut-off is made, the concepts of income, market and sales price do not form a cluster like it was the case when the total numbers of concepts was considered.

7.4 Protocol Analysis

In section 6.5.3 we described that besides "building" -and eliciting- cognitive maps which correspond to the static knowledge aspects, the interviewees were asked to solve some problems in order to get insights into the dynamic knowledge aspects of the farmers, i.e., their reasoning patterns regarding sustainable agriculture. The 80 participants had to solve three real-world tasks in order to get a grip on the reasoning patterns that concern sustainability (see appendix II). This helped us to gauge the reasoning patterns of the farmers. The focus was on the operationalization of sustainable thinking in order to answer the research question: What are the differences in knowledge aspects (static and dynamic) between farmers that favor sustainable practices and farmers that do not? -(see section 5.3). Understanding was constructed through the exploration of participants' own words. The data were coded and categorized and the content was analyzed from a total of 80 interviews. Each interview consisted of three tasks that had to be solved (section 6.4). Table 7.10 shows the solutions of the tasks that were solved. All the tasks were solved. Task 1, the shortest one, took on average less than a minute to be solved. Tasks 2 and 3 took 8 minutes on average to be solved. Task 1 referred to the possible improvements that tractors may have. It was thought as a "warming-up" exercise in order to practice or help interviewees with the talk-aloud exercise. However, it gave insights in the view that farmers have regarding one of the most used agricultural machines. Three quarters of the interviewees mentioned a need to make the mechanical parts uniform among tractors. In this way reparations could be made easier. Half of the interviewees consider it important to decrease the fuel consumption, mostly for economic reasons. Noise reduction and comfort had a similar amount of mentionings.

Task 2 confronted the farmer with the decision to accept, or not, a new soil quality enhancer. Proper soil management is one of the most important aspects of the agricultural system (see chapter 2). In general, the participants mentioned that there was a lack of information of the product. They recognized that assessment strategies (of the new product) are needed to satisfy multiple goals and that opinions will vary among end-users. Below, we provide some quotes.

"…I don't know this product exactly. I don't know the features. So I first have to spend some time to look what the product is. What is in it? How much will it cost? In what way will it work…"

Those who were willing to do a test with the soil quality enhancer, might do so only if there would be more information available.

"…First I want to know how it works, technically seen. Scientifically even maybe. A pilot farm, or in the neighborhood. Just test it. I am also ready to test it myself first…"

Those who refused to accept the product gave the same reason. They need more information about the product before to try it.

"...That depends on what the cost will be. Also it has to work. I base my conclusion if it works or not on the quality of the product. Now the quality is not known (at least in the Netherlands). I will search for advice about the product..."

Table 7.10 Solution times and description of the kind of answers

<table>
<tr><th></th><th colspan="2">Task 1</th><th>Task 2</th><th colspan="2">Task 3</th></tr>
<tr><td>Solving Time
Average (seconds)
SD (seconds)</td><td colspan="2">52
29</td><td>520
166</td><td colspan="2">503
120</td></tr>
<tr><td>% of interviews that completed the task</td><td colspan="2">100%</td><td>100%</td><td colspan="2">100%</td></tr>
<tr><td>Main Topic</td><td colspan="2">Improvement of tractors</td><td>Introduction of a new product to enhance soil quality</td><td colspan="2">Pest control</td></tr>
<tr><td rowspan="4">Solution Classification</td><td>Standardization</td><td>74% of interviewees</td><td rowspan="2">39 % of the interviewees may be willing to try the soil quality enhancer.</td><td rowspan="2">Chemical control</td><td rowspan="2">58% of interviewees</td></tr>
<tr><td>Decrease in fuel consumption</td><td>57% of interviewees</td></tr>
<tr><td>Noise reduction</td><td>34% of Interviewees</td><td rowspan="2">61 % will not try the soil quality enhancer due mainly to the lack of information of the product´s performance</td><td rowspan="2">Other type of controls such as:
Growing of resistant breeds
Maintaining soil in good conditions
Use of suppression methods</td><td rowspan="2">42 % of interviewees</td></tr>
<tr><td>More comfort</td><td>32% of Interviewees</td></tr>
</table>

Task 3 presented the farmer with a pest control issue. Chemical pest control is still the predominant type of pest control today, although its long-term effects led to a renewed interest in other forms of pest control (see chapter 2). The answers show that it is an issue that faces the farmer with a serious dilemma. As one of the interviewees mentioned:

“...It’s not as easy as black and white. It is a tailor made job. Try to lower your dosages for example and try that year after year…”.

Almost half of the farmers would advise the use of chemicals as a first option In general, the farmers do not consider chemical pest control something negative per se but they recognize that the amounts of chemical products should be minimized.

“ …Then about the usage of chemicals, you can make a choice in what to use, how much and how expensive...”.

“...I think that the substances (pesticides) since 20 years became a lot better. They have a lot less impact on the environment. And they are controlled really good…”

The other half would suggest looking first for other alternatives. However, some recognized that the chemicals were at some point the only solution they had.

“...If you treat your soil in a good way you are one step before and you look ahead. Plants need the soil to grow and if the soil is good, plants have the originally condition to grow in a healthy and good way. But if diseases (tend to) develop themselves I have to spray against these. Diseases like “phytopythora” are hard to destroy with biological methods...”

Hence, we had 240 written protocols that had to be analyzed. Content analysis was supported by the use of *NVivo 9*©. We earlier defined (chapter 4) five major qualities as indicators of sustainable thinking (see table 7.11). These qualities were identified as (1) cooperation, (2) feedback, (3) integration, 4) interconnections and (5) time horizon.

Table 7.11 Aspects of Reasoning Patterns and explanation of levels

Systemic Quality	*Level 1*	*Level 2*	*Level 3*	*Level 4*
Cooperation (indicates the preference to work alone or with other farmers)	The interviewee prefers to work alone. 1 *“I develop myself”*	The interviewee thinks about the possibility of other options but he acts as a passive receiver of the information. *“There are so many products, every year there is someone who says: this is good for the soil, and you have to judge if you can do something with that”*	The interviewee explicitly takes other points of view into his thoughts. He exchanges information, He asks for external advice. *“and we heard about colleagues who have used them but we first want to hear if they work. There are just so many on the market nowadays. We have tried it in the past”*	The interviewee learns from others (he may participate in study groups). *“So going to colleague farmers who are biological and talk to them, what the possibilities are and in what ways I could change, and what I need for that”*
Feedback (indicates the presence of relationships among concepts)	The interviewee does not find any relationship.	The interviewee mentions the relationship in one direction (cause-effect). *“If the pH goes up by using Biochar then it also will affect the life in the soil”*	The interviewee mentions several relationships (even though they are still unidirectional). *“Soil life depends of the crop rotation. I have a lot of grains. And this has a good influence on the soil. I am aware of the fact that diseases could show everywhere at every time. For the beets I use also several resistant races”*	The interviewee mentions bidirectional relationships. *“And then you have to stimulate your soil life in the top from the start up again”*

Table 7.11 Aspects of Reasoning Patterns and explanation of levels (Continuation)

Systemic Quality	***Level 1***	***Level 2***	***Level 3***	***Level 4***
Integration (indicates the use of several elements into the solution of a task)	The interviewee does not see a dilemma on the story that is presented to him.	The interviewee has difficulties to "see" the dilemma. *"We use the tradional stuff. And nothing more"*	The interviewee sees the dilemma but he is not able to propose a (possible) solution to face it. *"So from that point of view you have to be on time with your chemicals, but on the other side, not more than necessary"*	The interviewee describes a plan to face the dilemma. *"And I rather not use it, because then you will destroy everything in your soil. If I use a lot of chemicals, first of all it will cost me lots of money, and second if my son becomes a farmer in the future, he will get land with really low soil fertility. Then it would take him lots of years to get it right again."*
Interconnections (indicates the presence of links between People, Planet and Profit dimensions)	The interviewee mentions that he lacks information to understand the dilemma that is shown.	The interviewee mentions concepts that can be classified among one of the P's of the Triple Bottom Line. *"The advice would be that you have to base your decision in the end to the financial results"*	The interviewee is aware of concepts that can be classified among two P´s from the Bottom Line Approach. *"I know it cost a lot of money but I want to be sure that I can harvest a healthy potato. To my experience this is the best method".*	The interviewee mentions concepts that can be related to the three P´s of the Triple Bottom Line. *"To try to keep the nutrients at a decent level. But that becomes each year more difficult, because of legislation I have to follow. We can use less nitrogen and less phosphate, potassium is a product which will become more expensive in the future"*

Table 7.11 Aspects of Reasoning Patterns and explanation of levels (Continuation)

Syatemic Quality	*Level 1*	*Level 2*	*Level 3*	*Level 4*
Time Horizon (indicates the time framework)	He mentions the concept of time in an ambiguous way. He focuses on the here and now. *"I will shuffle a lot in the coming periods"*	The Interviewee focuses on the near future (1 year time framework for example). *"The advice will be: Use for 25% non-chemical methods, continue that for 2 years and based on that you take further steps"*	The interviewee focuses on middle term events that may affect there and then (more than 3 years). *"You don't use it for one year, for more years I think"*	The interviewee focuses on long term events that may affect there and then (more than 10 years). *"And maybe it takes a couple of years. For instance if this turns out to be a good investment in 10 or 15 years, then we definitely would consider using it"*

Each quality is described in terms of levels. Level one reflects the reasoning patterns that are less sustainability oriented. Level two reflects a tendency towards a less sustainable thinking. Level three leans toward sustainable thinking. Level four indicates the reasoning patterns that are most sustainable oriented.

7.4.1 Narrative analysis

In order to analyze the different protocols we used content analysis. Content analysis is a systematic, replicable technique for summarizing communicated material into fewer content categories based on explicit rules of coding analysis to ascertain its meaning (Stemler, 2001). The approach allows the researcher to focus on the content and context through emerging themes based on the frequency of occurrences (Ritchie, Spencer, & O'Connor, 2003). It can be viewed as a way for "counting interpretations of content" (Krippendorff, 2004).

Content analysis involves systematic coding procedures. The coding in this study was made in line with recommendations provided by Lincoln and Guba (1985). As data was gathered, the information was continually analyzed using sentences as coding units in the transcriptions from the protocols. As the analysis progressed, the software program *NVivo 9©* provided a much more structured and rigorous data management and analysis approach (see appendix III). The *NVivo 9©* software allows for relevant text to be coded as nodes. These nodes can represent a code, a theme, or an idea for later investigation. These coded sections, or nodes, ultimately were formed by the systemic qualities of sustainability already defined.

7.4.2 Major Themes

Content analysis of 80 data sources, gathered with the think-aloud protocols, yielded reasoning patterns relative to the manner in which farmers relate their thinking about and discussing the concepts of sustainability and its relationship to agricultural issues. The narrative was analyzed relating it to the different independent variables that were defined in chapter 5. Table 7.12 shows the profiles of the farmers divided by age. The profile was made based on the total number of coding references calculated with *NVivo 9©* -. The total number of references for each systemic quality is calculated based on the coding explained in table 7.11. The reasoning patterns in table 7.10 suggest that old and young farmers differ mainly on the systemic quality of the time horizon. Old farmers' answers focus on long term events.

- *"I look at the levels of phosphate, potassium and nitrogen in my soil and they should be at a level on which the soil quality stays durable for the future."*
- *"Well the next generations have to live with it as well, so it determines everything".*

Young farmers mention the concept of time in an ambiguous way and they focus on the here and now.

- *"I will shuffle a lot in the coming periods"*
- *"You have to search for the plants with the best future results and the highest resistant rates with such a result that you have to use fewer suppression products."*

Table 7.12 Reasoning patterns for farmers depending on their age

	OLD (n=36)				**YOUNG** (n=44)			
CONCEPTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
COOPERATION			X				X	
FEEDBACK			X				X	
INTEGRATION			X				X	
INTERCONNECTION		X				X		
TIME HORIZON				X	X			

NVivo 9© also permits the creation of tree maps. A tree map is a diagram that shows hierarchical data as a set of nested rectangles of varying sizes. A tree map compares the number of coding references included in a node (nodes are data segments gathered together). A node with a large number of coding references would display a large rectangle. The tree map is scaled to best fit the available space, so the sizes of the rectangles should be considered in relation to each other, rather than as an absolute number. Both groups –old and young- referred to soil and chemicals in a similar way, indicated by the similar size of their rectangles in the tree maps (shaded rectangles). However on a second level (shaded ovals), old farmers referred to land and quality (figure 7.11) while young farmers referred to grow and to their specific product (figure 7.12).

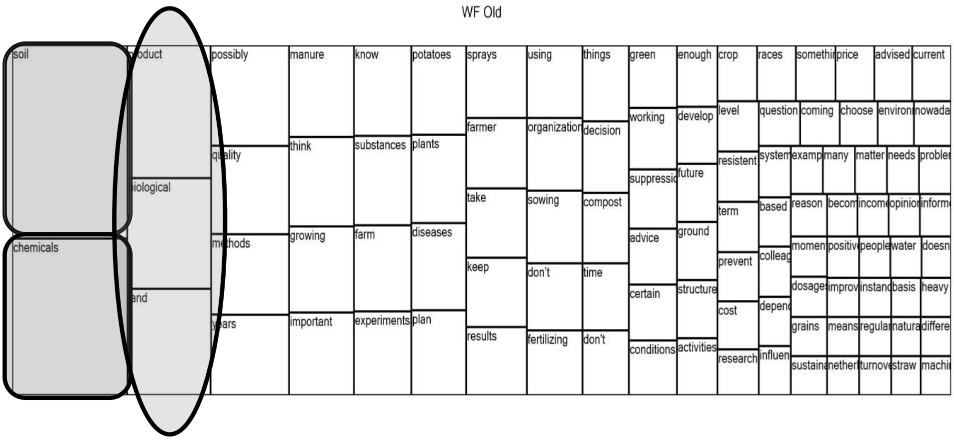


Figure 7.11 Tree map for old farmers

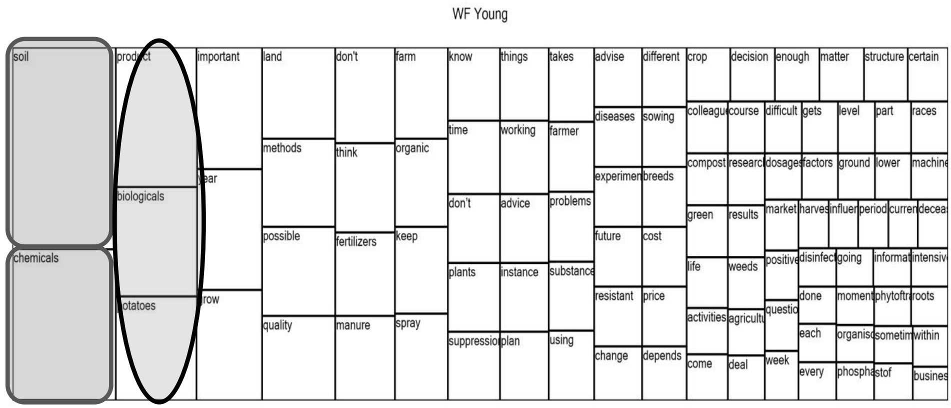


Fig. 7.12 Tree map for young farmers

The systemic qualities profiles of participants in the Veldleeuwerik project are shown in table 13. The interviewees differ in all systemic qualities. Interviewees that participated in the project show a tendency to include more systemic qualities in their thinking. In the case of cooperation, participants of the Veldleeuwerik project showed that they explicitly interact with other farmers in a more active way.

- *"So going to colleague farmers who are biological and talk to them, what the possibilities are and in what ways I could change, and what I need for that."*

- *"I participate in globalcap. Someone independent comes onto my land who checks it"*

Even though farmers that did not take part in the project acknowledged that they ask for external advice, they also expressed that they prefer to find out solutions by themselves.

- *"As you see with these experiments I try to figure out what's the best for the soil to get the best products out of it."*

- *"Most of the time I do this research on my own."*

In the feedback aspect, the participants of the veldleeuwerik project mentioned several relationships. The farmers that did not take part on the project mentioned few relationships. Interviewees that took part in the project were able to describe concrete actions to face the dilemma that was presented to them.

- *"10 years ago I started to see that the* soil quality *was going down. To resolve that I brought the old layers back up into the soil. That's the first thing."*

Non-Veldleeuwerik participants were not always able to propose alternatives, even though they recognized they had a problem.

- *"So he should try to search for good alternatives, but there is a big chance there are no non-chemical alternatives. Also because there hasn't been done enough research about such alternatives."*

While answering the tasks, the interviewees that participated in the project included terms that belonged at least to two of the three P´s within the TBL approach.

- *"You can deal with the problem for a part by changing crops. As a conclusion, you cannot work without chemicals. You cannot do it all by hand. Because of the time and employees you don't have."*

- *"First I would decide on economic reasons, and second I look at my soil."*

Non veldleeuwerik interviewees included, in general, only one term in their answers.

- *"I want to see clear results of the product so I can make a cost/benefit analysis"*

- *"I can create a higher income with it."*

Time horizon was the systemic quality that showed the biggest difference. Those who participated in the project focused on long term events, whereas the rest mentioned this ambiguously or with a focus on present events.

Table 7.13 Systemic qualities profile for farmers depending on their participation in sustainable project

	Non Participants on Sustainable Project (n=63)				**Participants on Sustainable Projects** (n=17)			
CONCEPTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
COOPERATION			X					X
FEEDBACK		X					X	
INTEGRATION			X					X
INTERCONNECTION		X					X	
TIMEHORIZON	X							X

The tree maps for both groups, figure 7.13 and figure 7.14, show that soil and chemicals were the most used concepts (shaded rectangles). The size of the rectangles in tree maps suggests that the concept of soil is more important among the Veldleeuwerik farmers. The tree maps also suggest that land is important for Veldleeuwerik farmers since they had more references to this concept (shaded oval). Non-Veldleeuwerik farmers referred more to product (shaded oval).

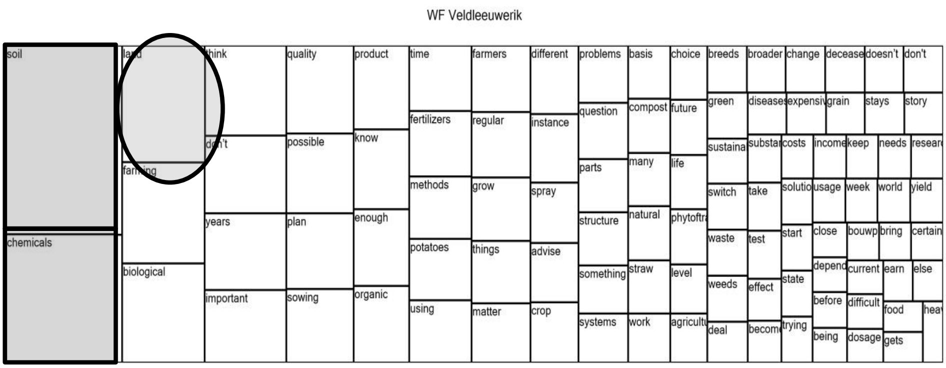


Fig. 7.13 Tree map for Veldleeuwerik farmers

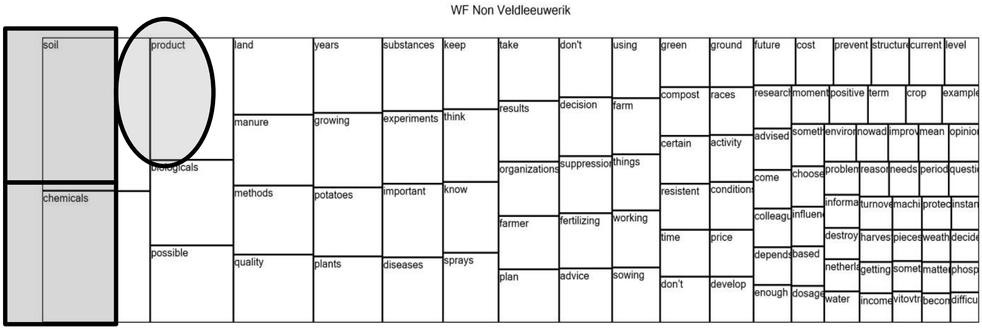


Fig. 7.14 Tree map for Non-Veldleeuwerik farmers

7.5 Hypothesis Testing

In section 5.5 we have drawn four hypotheses derived from the conceptual model. The results of the hypotheses testing are presented in the present section.

7.5.1 Education Level

In section 5.4.2 we discussed the importance of education in order to build awareness about sustainable agriculture. Education should contribute to the acquisition of concepts that can enrich the static aspects of knowledge of sustainability. We differentiated the farmers in two groups, those with higher education, and those with a vocational or lower level education. We formulated the following hypotheses:

1) H1a: Higher educated farmers and lower educated farmers differ in the number of KoS concepts that can be classified within each category (3P's)

Comparing the average number of concepts used for each one of the 3P's, an independent samples t-test revealed that regarding Profit there is a difference ($t= 2.852$, $p=0.006$). The farmers with vocational level use on average more Profit concepts ($mean= 4.96$, $SD= 1.664$) than the farmers with higher education ($mean=3.78$, $SD=1.928$). Regarding People, an independent samples test showed that there is no difference ($t= 0.969$, $p=0.336$) in the average number of concepts from the farmers that pursued a vocational education ($mean=5.06$, $SD=1.117$) compared to the highly educated farmers ($mean=4.81$, $SD=0.921$). In the case of Planet, the independent samples t-test reveals that there is no difference ($t=-1.941$, $p=0.056$) in the average number of concepts used by the farmers with vocational level (mean=7.11, SD=1.948) and farmers with higher education (mean=8.00, SD=1.901). This means that hypothesis 1a is rejected for Planet and People but not for the Profit concepts.

2) H1b: Higher educated farmers include more KoS references in their protocols than less educated farmers do.

The reasoning patterns according to level of education are shown in table 7.14. High educated farmers are more inclined to think on the long term.

- *“On the short term it is a solution, but in 5 or 10 years this is not enough”*

- *“...and also that on the long term you can still use the soil, so that in 100 years we can still produce food.”*

Low educated farmers either referred to the time in an ambiguous way or they did not specifically referred to the long term.

- *“The future will be a mix of chemical and non-chemical methods.”*

We expected that the medium educated farmers were able to identify just few –unidirectional- relationships whereas the high educated farmers were expected to mention bidirectional relationships. In both groups the interviewees mentioned several relationships (even though they are still unidirectional).

- *“First you have to know where to start with. First you have to care for clean land. Then you can take the decision to go biological.”*

Regarding the interconnections, both groups refer most to one of the three themes of the Triple Bottom Line Approach. This suggests that our hypothesis is supported only in the concept of long time horizon.

Table 7.14 Reasoning patterns according to level of education

	Higher Education Level (n=27)				**Medium/Low Education Level** (n=53)			
CONCEPTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
COOPERATION			X				X	
FEEDBACK			X				X	
INTEGRATION			X				X	
INTERCONNECTION		X				X		
TIME HORIZON				X	X			

NVivo 9© allows clustering of nodes by word similarity. The words contained in the selected nodes were compared. Nodes that have a higher degree of similarity based on the occurrence and frequency of words are shown clustered together. Nodes that have a lower degree of similarity based on the occurrence and frequency of words are displayed further apart. Figure 7.15 and 7.16 show part of the cluster analysis for the farmers according to their educational level. Figure 7.15 indicates that low educated farmers included Planet concepts in their answers (shaded circles). Figure 7.16 shows the cluster analysis for the high educated farmers. It suggests that when thinking about land, the farmers think about the future (shaded circle). They also include concepts of Profit and not as many concepts of Planet as the lower educated farmers do (shaded rectangle). These findings suggest that the more educated the farmer the more KoS concepts are included in the verbal protocol.

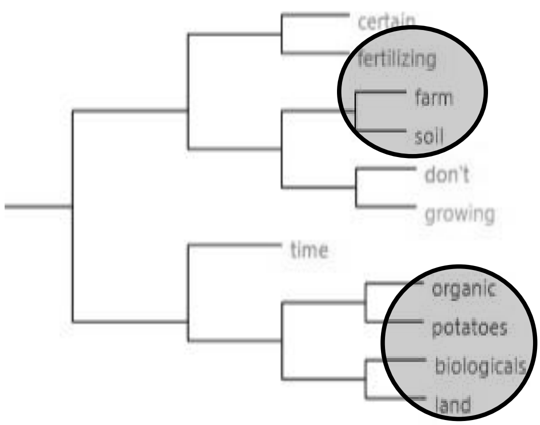


Fig. 7.15 Dendrogram low educated farmer

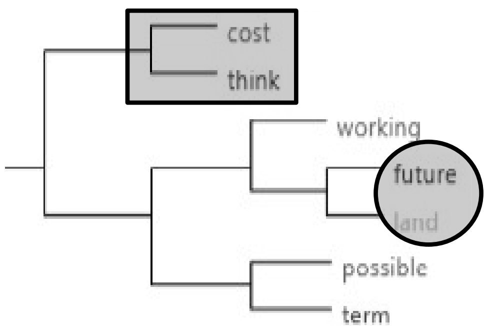


Fig.7.16 Dendrogram high educated farmer

7.5.2 Diversification

We discussed in section 5.4.1 that crop diversification promotes and enhances agro-ecosystem health involving biodiversity, biological cycles and soil biological activity. This requires that farmers consider several factors while performing their enterprise. Therefore we formulate the following hypotheses

1) H2a: The more diversified the farmer, the more complex the cognitive map.

We divided the farmers into two groups, the low and medium diversified with less than 4 crops and the high diversified with 5 or more crops. Since we have a strong a priori reason for expecting one effect in one direction a one-sided independent samples t-test was performed. The independent samples t-test revealed that there is a difference (t= 1.85, p =0.034) in the average inverse of the map densities when we divided the farmers into low diversified farmers (mean=58.2212, SD=17.2529) and high diversified farmers (mean= 50.7189, SD= 15.7842). This means that hypothesis 2a is accepted.

2) H2b: The more diversified the farmer the higher the level of systemic qualities in the protocol's profile

The farmers that presented low crop diversification presented similar reasoning patterns (table 7. 15) to farmers with a high crop diversification. Both groups have a similar level of cooperation and feedback.

- *"If I use a lot of chemicals, first of all it will cost me lots of money, and second if my son becomes a farmer in the future, he will get land with really low* soil fertility. *Then it would take him lots of years to get it right again"*

- *"Second, the use of good mostly complicated chemicals needs a lot of energy as well, for example the need for an extra strong tractor which uses more fuel"*

Table 7.15 Reasoning patterns according to level of diversification

	High Diversification (n=25)				**Low Diversification Level** (n=55)			
CONCEPTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
COOPERATION			X				X	
FEEDBACK		X					X	
INTEGRATION				X			X	
INTERCONNECTION		X				X		
TIME HORIZON	X							X

Farmers with high crop diversification mentioned the concept of time horizon ambiguously. They referred to the systemic quality of integration since they were able to propose possible solutions to face the dilemmas.

- *"At this moment I use preventive, intensive research (study) to keep eventual damage as little as possible."*

- *"You have to search for the plants with the best future results and the highest resistant rates with a result that you have to use fewer suppression products."*

Both groups have similar levels of interconnection. Farmers are normally focused either on the Planet or the Profit themes. The People theme was barely referred to.

- *"That depends on the price. That's very important, how it works out financially."*

- *"You should write it down, that we do use chemicals, but in the most environmental friendly way we can."*

There is no evidence that indicates that the more diversified farmers are the higher the level of systemic qualities.

7.5.3 Farming Expertise

Earlier in 5.4.3, we discussed the relevance of expertise. The cognitive or knowledge approach that we adopt considers that individual farmer knowledge constitutes an extensive realm of accumulated practical knowledge (see section 4.2). The formulated hypotheses for this situation are:

1) H3a: The average map density of experienced farmers and novice farmers differs.

Farmers were divided into two groups, novice and experts according to the number of years that they worked on a farm. We expected that average of the inverse of the map density for expert farmers (mean=58.1327, SD=18.0609) was different from the novice farmers (mean=52.8244, SD= 15.3651). An independent samples t-test revealed that there is a difference but the difference is not significant (t=-1.383, p=0.171). This means that hypothesis 3_a is rejected.

2) H3b: The more expertise the farmer has the higher the level of systemic qualities in his protocol's profile

Table 7.16 indicates that farmers with a low degree of expertise consider other points of view when they are confronted with a task. Novice farmers also ask for more external advice than farmers with more expertise do.

- *"but I would turn to several farmers who work without chemicals to gain a lot of information. And I want research. It isn't an easy decision".*

Table 7.16 Reasoning patterns according to degree of expertise

	Novice Expertise (n=46)				**High Expertise** (n=34)			
CONCEPTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
COOPERATION			X				X	
FEEDBACK			X				X	
INTEGRATION				X			X	
INTERCONNECTION			X			X		
TIME HORIZON				X	X			

The farmers with a higher degree of expertise favored first working on their own and then confront their ideas with other colleagues.

- *"Well, everybody has to make up their minds about such things for themselves, right?"*
- *"So based on experience you need to take this decision."*
- *"And sharing information with colleagues."*
- *"There are a lot of professional organizations that work with new products and first look at the results of them. If they advise the product as being good for the turnover than I should decide to use the new product"*

The interviewees with low expertise linked concepts related to two of the 3P´s from the TBL approach. The farmers with more expertise referred to concepts –frequently- related to either Planet or Profit in the solutions of the tasks. Regarding the time horizon, novice farmers focus on long term events

- *"Price isn't even the most important, as long as the quality is high and for the long term the soil will have a better yield"*

Expert farmers focus on present events.

- *"At this moment I use preventive, intensive research (study) to keep eventual damage as little as possible"*

There is no evidence that indicates that expert farmers present a higher level of systemic qualities than novice farmers

7.5.3 Age

Age is discussed in section 5.4.3 together with experience. Although an important farmer characteristic, there appears to be no clear correlation between age and best agricultural practice adoption. Regarding attitudes towards financial matters, young adults are at an unpredictable time of life, with many experiencing changing circumstances having different engagement levels with respect to financial information. Therefore, we formulated the following hypothesis

H4: Older farmers and young farmers differ in the number of Profit concepts within their cognitive maps

Farmers were also classified as young and old. Regarding the Profit concepts used to build the cognitive maps, an independent sample t-test revealed that there is a difference ($t=2.163$, $p=0.034$) among the concepts selected by young farmers (mean= 4.95, SD=1.817) and the concepts selected by old farmers (mean=4.08, SD= 1.763). This implies that hypothesis 4 is accepted.

7.6 Open Questions

In section 6.5.4, we mentioned that the last section of the knowledge elicitation instrument, the questionnaire, consisted of four open questions. The interviewees had already been involved around one hour in the different assignments from the knowledge elicitation instrument. Hence, these questions were aimed only at exploring the involvement of the farmer in activities aimed at promoting sustainability in the last three years. Table 7.17 summarizes the findings from the open questions.

The first question was related to the attendance to meetings where the interviewee considered sustainability was discussed. 11 farmers participated in 20 or more projects; one of them mentioned that he attended 90 meetings. It would be interesting to know which kinds of meetings were taken into consideration in their answers. In this open question, a meeting could be an informal meeting with fellow colleagues, an assembly or a study group. Regarding People, 18% farmers mentioned they attended these meetings because it was required to obtain a license to spray their fields. A small portion of the interviewees (5%) mentioned that during the meetings they discussed Profit aspects such as increasing production yield. Planet issues such as taking care of the soil, and reduction in the use of chemical products were mentioned by 46% of the interviewees. Other farmers (31%) mentioned that they acquired "general knowledge" (without going in more detail) at these meetings.

Table 7.17 Open questions from the Knowledge elicitation instrument

	Question 1	Question 2	Question 3	Question 4
Topic	Attendance to meetings related with sustainability	Participation in projects they considered as sustainable	Actions taken to improve the living environment of plants and animals (in their farm)	Actions taken to improve the soil and water quality (in their farm)
% Interviewees that answered	100	100	100	100
Type of Answer	97.5% of the participants attended at least one meeting	70% of the participants take part in at least 1 project.	60% considered that they took an action. 40% Considered that they did not do anything special	97.5 % indicated that they took actions to improve soil qualities 75% Considered that they did some activities to improve water quality

The second question regarded the participation on a project farmers themselves considered sustainable. In section 7.3.1, we mentioned that a group of farmers made reference to a project aimed at promoting sustainable farming practices. This project is included in the answers to this question. From the interviewees that took part on a sustainable project 21% took part on a project that aimed at covering the different aspects of TBL. The rest of the interviewees (79%) took part on projects related to Planet (mostly to improve the soil quality. The third question related to the actions farmers had tried in order to improve the living environment of plants and animals. From the 48 farmers that answer positively, 47 answered that they were concerned about birds. One mentioned he planted trees. The last questioned covered the activities that farmers had done to improve soil and water quality. Among the activities that farmers did in order to improve the soil quality, the use of green fertilizers was the most mentioned (66.6%) followed by using less chemicals (21.8%). Regarding the water quality, spray control was mentioned (41.6% times) followed by less use of chemical (28.3% mentions).

7.7 Secondary Analysis

Secondary analysis involves the use of existing data in order to pursue a research interest which is distinct from that of the original work (Vogel and Clarke-Steffen 1997). We studied which concepts are relevant in the cognitive maps drawn by farmers. Now, we would like to explore the type of relationships that were selected. We also analyzed the different cognitive maps and tasks that 80 farmers from the Netherlands have solved. We divided the farmers according to their educational level, age, expertise and degree of diversification. We also want to concentrate a selective focus on a sub-set of the sample from the original study.

7.7.1 Type of relationships within cognitive maps.

The interviewees could select among four types of relations: 1) Influences, 2) Depends on, 3) Requires, 4) Leads to, and 5) Consists of. Table 7.18 summarizes the results found.

Table 7.18 Relations used to build the cognitive maps

Relation	Influences	Depends on	Leads to	Requires	Consists of	Four relations considered
Total	950	294	248	49	29	1,570
Average per map	12	4	3	1	0,4	20
Maximum on a map	30	15	9	10	5	45
Minimum on a map	3	1	1	1	1	9
Percentage of farmers that used the relationship	100	89	76	29	18	100

On average, each map contained 20 relations. The maximum number of relations used was 45, whereas the minimum was 9. Farmers that used 15 or less relations represented 27.5% of the interviewees. Farmers that selected 30 relations or more were 7.5% of the interviewees. Regarding the different relations, “influences” was the most selected relation with a 89 %. “depends on” was used on 76% of the maps. An independent samples t-test revealed that there is a difference ($t=-1.432$, $p=0.156$). in the average number of relations used by interviewees that participated on the projects aimed at sustainable agriculture and those who did not participated. The participants that participated on such a project selected on more relations (mean= 22, SD= 6) than those who did not participate (mean= 19, SD= 7).

7.7.2 Reasoning patterns among Veldleeuwerik participants

We know that several farmers that were interviewed participated in a project aimed at promoting sustainable farming practices. This project included the participation in learning events, which serve as a forum for support and sharing information among farmers interested in sustainable practices. Among the participants of the sustainable project there were seven farmers that scored similar in the systemic qualities. We thought it was interesting to explore if there were some similarities among these farmers. The number of concepts used to build their cognitive maps was the same as the average of the whole sample (17 concepts). However, on average, they used more Planet concepts than the whole sample. They used, on average, less Profit concepts than the whole sample. (table 7.19).

Table 7. 19 Concepts mentioned in the cognitive maps of selected farmers

	Average number of concepts used to draw a cognitive map by selected farmers.	**Average number of concepts used to draw a cognitive map (whole sample).**
Total	17	17
Planet	9	6
People	5	5
Profit	4	5

We also obtained a tree map of this sub group of farmers (fig. 7.17). The tree map shows that soil was the most relevant term that they referred to in the solutions of the tasks. The soil term was followed by biological and chemicals. These farmers also included the term future in the solution of the tasks.

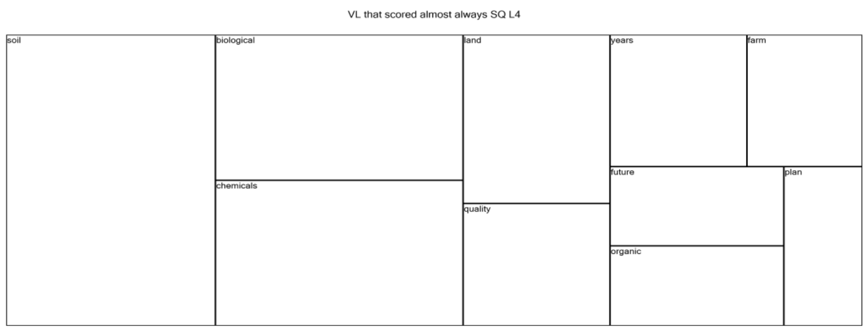


Fig. 7. 17 Tree map for selected farmers

These results suggest that participants of the project aiming at promoting sustainable practices think more about Planet and People than about Profit. However, we cannot state if this is due to their participation on the project or if they participated in the project because they already had this mindset.

7.8 Conclusions

This chapter first discussed the independent variables at a descriptive level. There were 80 participants in our study. The participants of the study are middle age adults. The participants were experienced in farming. The average size of the farms is bigger than the Dutch average. Equally, the average production of potatoes of the interviewees is higher than the Dutch average. Most of the farmers followed a vocational education (mainly in agricultural technical schools). Most of the farmers have a diversified farm regarding their crop production.

Secondly, we also studied the static elements of knowledge. It concerns cognitive maps "built" and elicited by the participants. The concepts included in the cognitive maps were classified according to the three themes of the Triple Bottom Line approach (Planet, Profit and People). The most chosen concepts for Planet were related to the topic of soil (such as soil structure, sowing plan). All the concepts included in Profit were relevant in building the cognitive maps. The most chosen concept for People was customer opinion. In general, concepts included in People were used with lower frequency. A group of 17 interviewees participated in a project aimed at promoting sustainable agricultural practices. Participants in this project choose, on average, more Planet concepts and less Profit concepts than non-participants in order to build their cognitive maps. Regarding People concepts there was no difference in the average number of concepts among groups. The findings concerning the density of the cognitive maps suggested that farmers that participated in this project presented also more complex thoughts about sustainability than non-participants do.

Thirdly, through cluster analysis we were able to identify four clusters within the participants in the study. Interviewees that are part of cluster number 1 used an equal number of concepts of People, Planet and Profit in their cognitive maps. Cognitive maps, part of cluster number 2, are Planet oriented. Farmers in this cluster used less Profit concepts than the other three clusters. Cluster number 3 consisted of farmers that are also Planet oriented but they selected People and Profit concepts with an equal number to a lesser extent. Cluster number 4 contained cognitive maps that were Profit oriented. Interviewees that belong to this cluster selected more Profit concepts than the other three clusters. The concepts of People and Planet were selected equally in this cluster.

Fourthly, multidimensional scaling (MDS) was used to identify dimensions where the concepts used to build cognitive maps can be considered similar. MDS for all farmers showed the dimensions of managerial (People) concepts and the Planet dimension. MDS for participants in the project, promoting sustainable practices, showed results concerning People and Planet. MDS for non-participants of the sustainable project showed the dimensions of Complexity and Planet.

In the fifth place, apart from the static elements of knowledge, this chapter deals with the dynamic elements of knowledge, the reasoning patterns of farmers. The reasoning patterns are relative to the manner in which farmers think and reason about sustainable agricultural issues. The results regarding the age of farmers suggest that old farmers focus more on long term events while young farmers focus on their present situation. Farmers that participated in the project aimed at promoting sustainable practices (Veldleeuwerik) have reasoning patterns that are more sustainability oriented than those who did not participate. Finally, in this chapter all hypotheses stated in the different relations in the concept model were tested. Table 7.20 gives an overview of these studied hypotheses and the effects found.

Table 7.20 Summary of empirical results

No.	Hypothesis	Effect
H1a	Higher educated farmers include more KoS concepts that can be classified within each category (3P´s) than lower educated farmers.	Rejected for “Planet” and “People” Accepted for “Profit”
H1b	Higher educated farmers include more KoS references in their protocols than less educated farmers do.	Accepted for the “Long Time Horizon” concept
H2a	The more diversified the farmer the more complex the cognitive map	Accepted
H2b	The more diversified the farmer the higher the level of systemic qualities in the protocol´s profile	Accepted for the “Integration” concept
H3a	Experienced farmers show a higher map density than novice farmers	Rejected
H3b	The more expertise the farmer has the higher the level of systemic qualities in his protocol’s profile	Rejected
H4	The older farmers show a larger number of “Profit” concepts within their cognitive maps	Accepted

8 DISCUSSION AND CONCLUSIONS

8.1 Discussion

In this study, we have made a review of the history of agriculture (see chapter 2). Agricultural practice is one of the most important events in human history. As such, we can tap its roots deep into the annals of so-called ‘primitive’ civilizations, by tracking back some 12,000 years into prehistory. What is new historically is the use of synthetic fertilizers introduced in abundance during the early part of the 20th century and chemical pesticides used in the second half. This along with massive public investments in modern scientific research for agriculture led to dramatic yield breakthroughs in the industrial countries. This period (110 years) is known, in the study of agriculture, as the period of modern, industrial, or conventional agriculture. This new modern agriculture has led to higher yields and profitability. In addition, several international agricultural research centers were created all over the world. Moreover, with faster-growing varieties and irrigation; they grew more crops on their land each year.

However, these practices also had shortcomings. Excessive and inappropriate use of fertilizers and pesticides has polluted waterways, poisoned agricultural workers, and killed beneficial insects and other wildlife. Irrigation practices have led to salt build-up and eventual abandonment of some of the best farming lands. Groundwater levels are retreating in areas where more water is being pumped for irrigation than can be replenished by the rains. Moreover, heavy dependence on a few major cereal varieties has led to loss of biodiversity on farms. As farmers began to use modern inputs for the first time there was an absence of (effective) regulation of water quality, input pricing, and subsidy policies that made modern inputs too cheap and encouraged excessive use of them, creating negative environmental impacts.

Sustainability has emerged as an alternative for agricultural systems to address the many constrains faced by conventional agriculture. Therefore, we devoted chapter 3 to the study of sustainability. Although there are still many definitions, it is widely accepted that being sustainable refers to the capacity of agriculture over time to contribute overall welfare by providing sufficient food and other goods and services in a way that three aspects are balanced. Those three elements are known as the Triple Bottom Line. The Planet element refers to ecologically sound practices that have little or zero effect on natural ecosystems, or even enhance environmental quality and the natural resource base upon which agriculture depends. The Profit element relates to a profitable activity. Profitability is conditioned by many factors such as crop production methods, farm characteristics, institutions, infrastructure, market access, regulations among others. The People element refers to the quality of life of those stakeholders who intervene within the agricultural system. It includes well-being and livability both individual and social.

Once that we covered the study of sustainable agriculture a question arises, how individuals represent the knowledge of sustainable agriculture in their minds? At an individual level knowledge is the basis for human action. Knowledge resides in the mind. Hence, chapter 4 was devoted to the study of knowledge. We started chapter 4 with an overview in cognitive science since the mind (where knowledge resides) is the domain subject of cognitive science. In chapter 2 we explained that we adopted a systemic approach in dealing with agricultural systems. Therefore, we consider the farm as a system. The farmer is considered a subsystem whereas the agricultural environment is a supra-system. Since our study focus on the individual, we argue that the adoption of a sustainable practice is ultimately a reasoning decision made by a farmer base on his knowledge structure. Therefore, cognitive factors are fundamental in agricultural actions, as can be seen from the conceptual model we developed in chapter 5. There, we positioned knowledge as the core of sustainability. In our study, there are two aspects of knowledge a static aspect, which deals with the way individual structures knowledge; and a dynamic aspect, which deals with the thinking or reasoning processes of individuals.

With the body of knowledge that we acquired in chapters 2, 3, and 4 we were able to: 1) identify the content that farmers might use in order to cultivate their land; 2) determine the levels of five systemic qualities in the reasoning process of farmers; 3) develop an instrument in order to elicit content of knowledge and reasoning patterns; 4) apply the instrument and test some hypothesis. This dissertation addressed the issues discussed above by means of three research questions. The results we found are used to answer the research questions.

8.2 Research Questions

This dissertation argues that sustainability can help to diminish and/or eliminate the negative impacts that conventional agriculture has caused. Knowledge of Sustainability can be used by farmers in order to support decision making process about their enterprise. Therefore our leading research question regarding this was:

1) *What is the relation between agriculture, sustainability, and knowledge?*

This dissertation assumes that farmers are information-processing systems (see chapter 4). In our opinion, the study of how sustainability, as represented in the mind of farmers, is an issue for cognitive sciences and knowledge engineering, not agriculture, although the knowledge of the practice of agriculture is essential for the research in knowledge representation. We took an approach that emphasized both cognitive sciences and sustainable agriculture. We argued that cognitive science has the methodology and theories for understanding sustainable mindset, but applying that methodology requires a deep understanding of sustainable agriculture. In contrast, sustainable agriculture has a deep understanding of this knowledge, but little understanding of the methodology and theory for eliciting knowledge aspects. As a result, developing the deep understanding needed to understand sustainable mindsets will require cognitive scientists to understand more about sustainability and sustainability practitioners to understand more about cognitive science. We were able to define the different aspects of knowledge of sustainable agriculture in terms of knowledge content and knowledge processes. The operationalization of the different knowledge aspects, the development a knowledge elicitation instrument and the analysis of the data obtained through the administration of the instrument to several farmers were the result of bringing these domains together. To understand knowledge of sustainable agriculture is essential to understand cognitive mechanisms and adopt cognitive methodologies in the research and intervention of agricultural practices. Our following associated research question therefore is:

2) *What kind of knowledge aspects do farmers have regarding sustainability?*

The essence of this dissertation is that sustainability and sustainable development can be better understood through a knowledge approach on a systemic basis. This implies that the specific path of sustainable agriculture as a process may vary from one individual to another as a function of the respective entity and significance factors. For example, a farmer that wants a good living might have a different goal and purpose to a politician who aims at a sustainable agriculture. Hence, it was necessary to consider farming systems in relation to different stakeholders. This led us to investigate the knowledge processes of the main actors in agriculture: the farmers. In section 3.4 we adopted the "view from space" perspective in order to look at an agricultural system. An agricultural system consist of a collection of actors that have their knowledge (own mental representations) regarding the agricultural system as a whole. The main actors in the system (farmers) have a cognitive model that supports the static aspects of knowledge (content) and the dynamic aspects of knowledge (reasoning process) on the agricultural system.

In order to make operational the static aspects of knowledge we chose agricultural concepts that are representative of one of the elements included in the Triple Bottom Line approach. We operationalized the dynamic knowledge aspects to gauge the systemic thinking qualities of farmers. All together, we have defined five different systemic qualities to be studied (section 4.5.1): (a) Integration (b) Time Horizon (c) Interconnections (d) Feedback (e) Cooperation. Once the operational definition was established, the next issue was the acquisition of knowledge.

Hence, the following associated research question was formulated:

3) *How is it possible to elicit knowledge of farmers?*

We focus on the knowledge content and on the processes of knowledge. Therefore, one of the challenges mentioned in chapter 1 was the elicitation of mental representations that farmers have. The static aspects of knowledge were elicited by means of cognitive maps (see chapter 6). They were used to verify dimensions of sustainability that were perceived by the farmers, as well as their ability to understand the relationships between these dimensions (People, Planet and Profit).Using cognitive maps supports the process of identifying knowledge and is also useful in order to better define what should be transmitted. This dissertation advocates that the study of (sustainable) agricultural systems could be based on the approach that allows looking for relations among all components of the agricultural system.

We used protocol analysis to acquire the dynamic aspects of knowledge since it allowed farmers to verbalize their thoughts in a manner that did not alter the thought sequences. Systems approach was useful while providing an understanding of how different concepts on a specific context work. In our work, sustainable oriented mindset refers to a special vocabulary with which farmers expressed their understanding of the dynamic complexity within agriculture. For example, more sustainable oriented farmers often describe the world in terms of time horizons, integration, interconnections, feedback, and cooperation. In brief, Cognitive mapping and protocol analysis are techniques that provide information regarding the knowledge content and knowledge processing (reasoning patterns) of farmers. Cognitive maps provide an assessment of how much knowledge is gained; protocol analysis allows an assessment of in what way knowledge is used. We developed an instrument to elicit the different aspects of knowledge from farmers (see chapter 6). The instrument consisted of four parts. The first contained general questions about the background of the interviewee. In the second part, cognitive maps were built. The third part consisted of solving problem tasks. The fourth part included a series of open questions. Based on this we formulated two sub-questions. The first sub-question (3a) is:

> *3a) What content of knowledge do (specific type of) farmers have regarding sustainability?*

In chapter 7 we presented the findings of our study. The static aspects of knowledge were elicited by means of cognitive maps (see section 7.3) which showed that farmers emphasize the category of Planet terms. The cluster analysis showed that farmers can be classified in different clusters where they favor either Planet or Profit. The MDS showed that, in general, the Profit concepts of market, sell price and income are closely related in the cognitive maps. We also found that farmers that are more educated select more Profit concepts to build their cognitive maps. Regarding the complexity of maps, we found that the more diversified the map, the more complex the cognitive map. Older farmers show a larger number of Profit concepts within their cognitive maps. The second sub-question (3b) is:

> *3b)What reasoning mechanisms do (specific types of) farmers use to favor sustainability?*

The dynamic aspects of knowledge were discussed in section 7.3. We were able to operationalize the reasoning of farmers into four categories that we named as systemic qualities. Each quality had four possible levels of sustainability. Each of the levels indicated the mindset of a farmer. We found that higher educated farmers include more references towards “long time horizon” than less educated farmers do. We also found that the more diversified the farmer the higher the level of integration of concepts in his protocol profile. In section 7.6 we explored the meanings of farmers through open questions. We found that the term sustainable is related mostly to environmental topics. For example, soil preservation, water management and reduction in the use of chemical products within their practices. Some farmers may think about sustainability as an obligation since they attended meetings where sustainability was a topic in order to obtain permission to spray their fields. Just a few farmers related meetings and/or projects about.

We have discussed that knowledge is the basis for action. Therefore, a question arises regarding the actions of farmers. Do they act in accordance with the mental representations and with the reasoning patterns, they have? In this respect, we knew that 17 interviewees participated in a project aimed at promoting sustainable farming practices called Veldleeuwerik. This project included the participation in learning events, which serve as a forum for support and sharing information among farmers interested in sustainable practices. The interviewees differ in all systemic qualities. Interviewees that participated in the project show a tendency to include more systemic qualities in their thinking. In the case of cooperation, participants of the Veldleeuwerik project showed that they explicitly interact with other farmers in a more active way. Time horizon was the systemic quality that showed the biggest difference. Those who participated in the project focused on long term events, whereas the rest mentioned this ambiguously or with a focus on present events. This lays the groundwork for future research in two routes. The first one is to divide the farmers according to their actual practices, for example, use of fertilizer, and to profile them in order to see how different groups act. The second one is knowledge transfer. That is if assessments are made pre and after an intervention (participation on a course) we would be able to evaluate how effective was the knowledge transfer given in the course.

8.3 Contribution of the Study

Our contribution in using a knowledge approach for sustainable agriculture is two-fold. First, we add to prior work (Faber, 2006; McElroy, 2008; Jorna, 2010) to show how a knowledge perspective can aid the understanding of sustainability. At the core of our findings is that the knowledge approach that we took offers a new perspective to address sustainable agriculture from the perspective of the individual farmer. It concerns knowledge as a criterion for guiding agriculture as it responds to change. We believe that considering the concepts that farmers use will help the transition from a conventional to a sustainable agriculture. This dissertation contributes to empirical research in the area of sustainable development. Specifically we addressed the knowledge component, which in our view has been barely discussed within the sustainable agriculture literature. Participants in this study concur with the notion that sustainability largely combines views from the environment with economic development. The different worldviews in classical and sustainable agriculture can and should be studied and evaluated more intensively.

Second, based on the results of our empirical study and on the theoretical underpinnings of agriculture, sustainability, knowledge management, and systems theory we identified concepts linked to sustainable agriculture (static knowledge aspects). We also offered a set of dynamic concepts that describe reasoning patterns among the interviewees (dynamic knowledge aspect). We found some differences among the farmers while we analyzed the static aspects of knowledge and the reasoning patterns. For example, higher educated farmer include more Profit concepts than lower educated farmers. We encountered that the more diversified the farmer the more complex the cognitive map. We also found that higher educated farmers include more "long time horizon" references in their protocols than less educated farmers. In the same way, the more diversified the farmer the higher the number of "integration" references in their protocol´s profile. Regarding the age of the farmers, we observed that older farmers show a larger number of Profit concepts within their cognitive maps. Such divergence in reasoning patterns as to how the systemic aspect manifests itself even among this small sample of farmers in the Netherlands tells us that more work is needed in order to unify criteria of how to achieve, support, and realize sustainable development.

8.4 Implications of the study

8.4.1 Draw more attention to different opinions

The research bridges multiple theoretical domains (knowledge management, sustainability, cognition, systems theory and agriculture). The contribution lies in the analyses of what cognitive resources farmers draw upon in this process. The instrument we developed, and the outcomes we got, helped to provide the means to and constrain the ways farmers can express and think about a phenomenon, and thus make researchers more informed and prepared when supporting farmers in sustainable practices.

8.4.2 BLGG AgroXpertus

For BLGG AgroXpertus, we believe it could be worthwhile to think about the knowledge approach in terms of mediated instruments and what implications such an approach may have and how information activities should be organized and what kind of support farmers need. In order to help BLGG when planning information activities, it may be useful to be aware of how farmers tackle the task of expressing their ideas of relationships and what cognitive resources they rely on. The enhancement of knowledge can help farmers to avoid the restriction of them solving only the immediate problems they face and to open it to a wider range of possibilities. A significant strength of the knowledge approach we used is that the modeling is close to natural language, which reflects how farmers are used to talk and think about their (farming) activities and decisions. This can be considered a model of cognition but mostly as a tool for reflective thinking. In the instrument we developed for this study, farmers were given tasks to solve. The purpose of these tasks was to capture the reasoning process that farmers follow during the exercise. However, as farmers think aloud they also begin to sense and express the complexity associated with farming decision making. We observed that some farmers came to a realization that sustainability has many interpretations, which are affected by the context in which sustainability is being applied. This is an opportunity for critical and reflective thinking. In so doing the farmer may have also a moment to deepen their own personal understanding of sustainability.

8.5 Limitations

Like any other empirical study, this work is not without limitations. First, farmers, the core stakeholders of agriculture, will not benefit from the knowledge in systems thinking. The only people who learned or will learn about systems thinking from this document are the people who created it. Truth is that we have spent a massive amount of time thinking about the farmer as an information processing system. However, we do not pretend to label or grade the farmers as an ultimate goal. We believe the instrument we developed can be useful as a feedback tool for self-assessment – so long as there is no labeling attached. The outcomes of our method can show farmers (or other stakeholders) where their current performance is, and what to aim for. Unfortunately, time constraints did not allow us to show the outcomes to the individuals we interviewed but it could be material for an upcoming research.

As part of our fieldwork, we often found that farmers (and researchers) ask for coaching in how to recognize what they have done well and what needs improvement. Depth of thinking is not something we can recognize or evaluate easily. Our method offers to be helpful in demonstrating where they need to go next in improving their agricultural and sustainable work. If we set up methods for farmers to gather data about their knowledge and self-assessment we would be more productive. For example, when farmers look at a term such as cooperation, feedback or long time horizon, you want to challenge them to think about this. Do I know what this term means? Do I understand what this means in relation to my farm? Can I explain how the concept of cooperation is applied? Can I teach this to others? We think that our instrument helps in this reflection process.

One of the clear limitations of this research is related to the ability to generalize our findings. More studies need to be performed to develop a comprehensive robust methodology. Another avenue for research is related to collaboration with other stakeholders for knowledge exchange, which might be inhibited by culture and trust barriers. A systems approach may uncover the processes that tend to inhibit knowledge sharing.

Despite their relatively wide usage, traditional cognitive mapping has some limitations. The largest problem is to identify those concepts and only those concepts that an individual perceives to be relevant by the domain in question. Participants are given a specific set of (well considered) concepts and are then required to build a map with them, regardless of whether they understand a particular item or perceive it to be important. It cannot be assumed that an individual´s cognitive map is comprised of an exhaustive set of concepts. The protocol analysis does have also some draw backs. The obvious one is that it is exceptionally time intensive (effectively limiting studies to small numbers), and the highly qualitative results do not permit statistical analysis, making comparisons among groups difficult. In addition, reliance on researchers to extract concepts and relationships from interview transcripts opens the technique up to potential biases and misjudgments. No technique is guaranteed to result in a complete and accurate representation of an expert´s knowledge, although our goal is to model the knowledge, not to extract or reproduce it in its entirety.

8.6 Suggestions for future research

8.6.1 Stakeholders inclusion

When it comes to sustainable agriculture, it should not be a single decision maker; rather a process of debate should take place among different actors. Cognitive mapping and protocol analysis can support knowledge elicitation from different stakeholders and to make it accessible in order to inform the debate and also they can organize the different knowledge aspects that emerge during the process. These techniques were used to disclose individual perceptions of consequences and explanations associated with concepts and they can be used by participants to communicate their understanding of the nature of the problem. The expected outcome is a set of insights that emerge from comparison of individual perspectives forming a richest possible picture of the problem situation. It is also convenient to consider the implication of farming systems from the perspective of different stakeholders, such as the farmer network and the regional and national levels. The outcome encourages parallel cognitive map and protocol studies for different key groups such as advisors and suppliers, besides farmers.

8.6.2 New hypotheses formulation

Our methodology determined what information the farmers perceive and what knowledge aspects they employ. It will not be possible for any farmer to deal with a problem situation adopting an objective approach. His personality traits, experiences, knowledge and interests will affect what is noticed and what is taken to be significant. Therefore, it is necessary to combine our knowledge approach with experiments that study the personality traits, mental representations and attitudes of farmers.

A few concrete examples of how the expansion of our methodology might translate into ongoing research will prove helpful. Through the use of the methods and measures described in this dissertation, researchers may seek to determine whether other aspects of cognition such as concepts and information retained in memory also play a role in the context of sustainable agriculture. For instance, farmers who decide to embrace sustainable practices might have more positive associations with this role than others (i.e., it may be semantically linked to many other concepts or roles) and may have richer knowledge structures concerning the role of sustainable practices and the activities it involves. Similarly, they may have different concepts of success and failure than researchers, governmental agencies, and/or suppliers. It may be better able to focus their attention on pertinent information. The instrument described earlier in this dissertation provides useful tools for investigating such possibilities. Finally, consider the question of why some farmers are more successful in profiting from sustainable practices than others. Many factors certainly play a role, but from a cognitive perspective, the consideration of a farmer as an information processing system plays a key role in our discussion. Again, the instrument described in this dissertation provides the means for studying such questions.

8.6.3 Different Applications

Our instrument was found to be a useful tool to represent knowledge structures. However, we believe that it can also help changes in farmers´ knowledge structure over time. Our instrument can also be useful to visualize how they organize their knowledge in a new way for example, after an intervention. It can be used as a pedagogical tool in study groups. It can show farmers how to be more aware of their own learning process. The farmer that discusses this with other farmers could also open his mind to other questions: what could I have done differently? How might I apply this thinking to other activities? Will I change my point of view about sustainability over time? By encouraging farmers to compare the differences between earlier and later maps or among other farmers –called consecutive knowledge snapshots-, they could evaluate the evolution of their ideas, knowledge, values and motivations on the subject. Seeing their progress from different perspectives could allow them to ponder the dynamics of sustainability.

8.7 Concluding remarks

When recognizing that the study of sustainable agriculture requires an adequate conceptualization of sustainability based on a specific context with the involvement of several stakeholders, an important question arises as to how one handles the inevitable tension between the divergent interests and worldviews and the need for the shared resolution of issues that emerge while working with sustainable agriculture. In sum, we believe that the methods and measures we used proved to be highly useful in the field of sustainable agriculture. Such tools can assist researchers in answering the important questions they have already posed and may also suggest new ones that could not readily be addressed in the absence of these techniques. In this way they may help us to gain new insights into the minds of different stakeholders —insights that might otherwise remain beyond our reach.

In concluding, it is important to note that a knowledge perspective should be viewed as complementary to, rather than incompatible with, other points of view in the study of sustainable agriculture—perspectives deriving from economics, strategy, sociology or environmental sciences. Many factors other than the cognitive ones influence farmers' actions and decisions and these, too, must be carefully considered. All that is being suggested here is that the cognitive perspective may provide necessary insights into the complex process of farming over and above those offered by the other points of view. Moreover, it seems possible that such benefits may accrue both to researchers wishing to obtain definitive answers to farmers basic ''why/how'' questions, and to practitioners attempting to assist farmers toward their goal of creating sustainable farms. Any perspective that offers the promise of both scientific progress and practical interventions would seem worthy of very careful attention indeed. However, there is no guarantee that such efforts will succeed—since there are never any guarantees in scientific research. Nevertheless, we believe that aiming at making this world a better planet to live for us, for those who lack a descent quality of life, and for the future generations is well worthwhile the attempt. We believe that a knowledge view towards sustainable agriculture can lead to creative solutions to these complex challenges.

APPENDICES

Appendix I. Map Densities for the 80 cognitive maps.

Interviewee	Selected Concepts	Relations Used in the Map	Map Density	Inverse Transformation (1/map density)
1	16	16	0.0161	62.1118
2	16	22	0.0222	45.0450
3	19	16	0.0161	62.1118
4	16	26	0.0262	38.1679
5	16	13	0.0131	76.3359
6	18	32	0.0323	30.9598
7	16	20	0.0202	49.5050
8	21	25	0.0252	39.6825
9	18	11	0.0111	90.0901
10	16	11	0.0111	90.0901
11	16	24	0.0242	41.3223
12	17	16	0.0161	62.1118
13	22	35	0.0353	28.3286
14	16	12	0.0121	82.6446
15	16	10	0.0101	99.0099
16	17	23	0.0232	43.1034
17	17	14	0.0141	70.9220
18	16	25	0.0252	39.6825
19	16	16	0.0161	62.1118
20	17	19	0.0192	52.0833
21	19	27	0.0272	36.7647
22	20	28	0.0282	35.4610
23	17	28	0.0282	35.4610
24	16	18	0.0181	55.2486
25	17	22	0.0222	45.0450
26	18	21	0.0212	47.1698
27	16	18	0.0181	55.2486
28	16	20	0.0202	49.5050
29	18	22	0.0222	45.0450
30	17	15	0.0151	66.2252
31	17	20	0.0202	49.5050

Interview	Selected Concepts	Relations Used in the Map	Map Density	Inverse Transformation (1/map density)
32	16	13	0.0131	76.3359
33	16	18	0.0181	55.2486
34	17	17	0.0171	58.4795
35	17	16	0.0161	62.1118
36	17	21	0.0212	47.1698
37	19	38	0.0383	26.1097
38	18	17	0.0171	58.4795
39	18	23	0.0232	43.1034
40	16	17	0.0171	58.4795
41	18	14	0.0141	70.9220
42	16	15	0.0151	66.2252
43	16	20	0.0202	49.5050
44	16	25	0.0252	39.6825
45	16	15	0.0151	66.2252
46	16	14	0.0141	70.9220
47	16	25	0.0252	39.6825
48	16	17	0.0171	58.4795
49	18	21	0.0212	47.1698
50	16	15	0.0151	66.2252
51	16	43	0.0433	23.0947
52	19	23	0.0232	43.1034
53	16	17	0.0171	58.4795
54	18	19	0.0192	52.0833
55	18	13	0.0131	76.3359
56	16	18	0.0181	55.2486
57	22	27	0.0272	36.7647
58	16	18	0.0181	55.2486
59	17	16	0.0161	62.1118
60	16	16	0.0161	62.1118
61	17	18	0.0181	55.2486
62	16	20	0.0202	49.5050
63	16	9	0.0091	109.8901
64	16	17	0.0171	58.4795
65	16	24	0.0242	41.3223
66	17	45	0.0454	22.0264
67	16	14	0.0141	70.9220
68	16	15	0.0151	66.2252
69	16	14	0.0141	70.9220

Interview	Selected Concepts	Relations Used in the Map	Map Density	Inverse Transformation (1/map density)
70	19	15	0.0151	66.2252
71	16	17	0.0171	58.4795
72	16	16	0.0161	62.1118
73	24	33	0.0333	30.0300
74	16	13	0.0131	76.3359
75	16	15	0.0151	66.2252
76	16	14	0.0141	70.9220
77	16	12	0.0121	82.6446
78	16	26	0.0262	38.1679
79	16	16	0.0161	62.1118
80	18	23	0.0232	43.1034

Appendix II. Knowledge Elicitation Instrument

ONDERZOEK RUG & BLGG Agroexpertus

Naam	
Straat	
Postcode	
Woonplaats	
Telefoonnummer	
Datum	

ALGEMENE GEGEVENS

1) U bent de bedrijfsleider? Zo nee, wat is uw functie?	
1) Wat is uw leeftijd?	
2) Hoe lang bent u als akkerbouwer werkzaam?	
3) Welke opleiding heeft u gehad m.b.t. de landbouw?	HLS MLS VMBO MBO HBO BOL BBL HAO LIr. Anders
4) Welke type aardappelengewas plant uw?	Consumptieaardappelen Pootaardappelen Zetmeelaardappelen
4) Wat is de aardappelopbrengst van het landbouwbedrijf? (ton/ha)	

5) Wat is de bedrijfsoppervlakte van uw bedrijf? (ha)	
6) Welk percentage is hiervan gepacht?	
7) Welk percentage is hiervan gehuurd?	
8) Welke andere gewassen (bovendien aardappelen) heeft u nog?	Brouwgerst Wintertarwe Uien Maïs Grasland Veeteelt Energiegewassen (koolzaad, energiemaïs) Suikerbieten Bloemen Gras Anders
7) Welke bouwplan hanteert u, met welke gewassen?	
8) Hebt u nog andere belangrijke bedrijfsactiviteiten?	Adviseur Camping Agro-toerisme In loondienst als werknemer Loonwerk Anders

TWEEDE SECTIE (computer of kaarten)

U zult als akkerbouwer vast wel eens hebben meegemaakt dat een college akkerbouwer anders over zaaiplanningsproblemen dacht dan u dat deed. Dit is ook niet vreemd gezien het feit dat ieder individu nu eenmaal uniek is. Zo bestaan er dus verschillen in de beelden die akkerbouwers hebben van poten planningsproblemen. Het doel van dit onderzoek is deze verschillen inzichtelijk te maken. De resultaten van dit onderzoek kunnen onder andere worden gebruikt om u als akkerbouwer beter te ondersteunen, door bijvoorbeeld u juist die informatie aan te bieden die u nodig heeft bij uw werkzaamheden als akkerbouwer. De eerder genoemde verschillen zullen onder andere inzichtelijk worden gemaakt met behulp van een spel. In dit opdracht zult u na een aantal stappen te hebben doorlopen een figuur hebben gemaakt waaraan te zien is hoe u tegen uw werkzaamheden als akkerbouwer aankijkt. Er zijn bij dit spel geen goede of foute antwoorden.

Stap 1 Start

Denk na over uw belangrijkste gewas. Welke factoren zijn belangrijk om de volgende zaaiperiode te plannen?

Stap 2 Begrijpen

Tijdens deze stap kunt u concepten en relaties kiezen. Bij deze stap dient u die concepten relaties te kiezen die u zoal tegenkomt bij uw werkzaamheden als akkerbouwer. U moet ten minste 16 concepten kiezen. Kies de concepten waar u van denkt dat die relevant zijn voor uw planning als akkerbouwer. Het is mogelijk om op een later moment wijzigingen in de door u gekozen objecten en relaties aan te brengen.

Stap 3 Domeinbeeld

In deze stap kunt u de door u gekozen begrippen plaatsen zoals op een kaart. Het verband geeft tussen de concepten kunt u weergeven door gebruik te maken van de door u gekozen relaties.

Nu kunt u beginnen met de stap 1

DERDE SECTIE

INLEIDING

Op de volgende pagina's worden opgaven weergegeven. In iedere opgave wordt een landbouwkwestie gepresenteerd. Wilt u bij het beantwoorden ***hardop denken***.

Succes bij de verwerking van de opgaven

OPDRACHT 1

Deze taak bestaat uit het bedenken van verbeteringen voor landbouwmachines.

Vraag

1) Tractoren zijn essentiële landbouwmachines. Kunt u vijf verbeteringen van tractoren verzinnen?

OPDRACHT 2

U leest het volgende verhaal in De Boerderij:

“Het concept van de kwaliteit van de toekomstige generaties komt vaak ter sprake tijdens discussies over duurzame landbouw: duurzame landbouw is die landbouw waardoor toekomstige generaties duurzaam gevoed kunnen worden. Dit betekent denken over de behoeften van vandaag en de behoeften van de toekomst. Mensen maken zich zorgen over de bodemkwaliteit op de langere termijn en dus over hoe de akkerbouwers bodemkwaliteitkwesties zullen hanteren.

In de afgelopen jaren is er een product ontwikkeld en onderzocht om de bodem te verbeteren: de naam van dit product is ‘Biochar’. Biochar wordt gemaakt door omzetting van agrarisch afval in een houtskoolachtig materiaal dat moeilijk afbreekt en daardoor koolstofdioxide afvangt. Door het gebruik van Biochar kan de bodem water en nutriënten beter vasthouden. Het zorgt voor vruchtbaardere bodems, ontmoedigt ontbossing en draagt bij aan het behoud van de diversiteit van het akkerland. Momenteel wordt Biochar het meest lokaal gebruikt in Afrika en Zuid-Amerika. De bijwerking van Biochar is dat het pH van de bodem kan verhogen. Daarnaast moeten strategieën, die het mogelijk maken om Biochar op grote schaal te verspreiden, nog worden ontwikkeld.”

Vragen

1) Kunt u beschrijven hoe u met de toekomstige bodemkwaliteitkwesties omgaat?

2) Kunt u uitleggen hoe u een beslissing zult nemen over het wel, dan wel niet gebruiken van Biochar om de bodemkwaliteit van uw bedrijf te verbeteren.

OPDRACHT 3

Gisteravond tijdens het praten met een collega vertelde hij de volgende situatie:

"Ik heb veel ervaring met de teelt van aardappelen; mijn grootvader is ongeveer 60 jaar geleden begonnen met de teelt van aardappelen. De laatste 40 jaar zijn er bestrijdingsmiddelen om ziekten en plagen te bestrijden. Het gebruik van grondontsmettingsmiddelen maakte de beheersing van aaltjes mogelijk. De afgelopen 10 jaar ben ik verantwoordelijk voor het bedrijf.

Ik heb gehoord dat bestrijdingsmiddelen een nadelig effect op het milieu hebben en ook de menselijke gezondheid kunnen beïnvloeden. Bestrijdingsmiddelen kunnen ook duur zijn. Hierdoor ben ik me de laatste tijd gaan afvragen of ik moet stoppen met het gebruik van deze bestrijdingsmiddelen. Ik weet echter niet zeker of niet-chemische methoden voldoende succesvol zijn om de pathogeens te beheersen en of ik hierdoor niet mijn voornaamste bron van inkomsten op het spel zet.

Ik heb je advies nodig: zal ik blijven werken met chemische producten of zal ik overstappen op niet-chemische methoden?"

Vragen

1) Kunt u aangeven hoe de collega deze situatie op kan lossen?

2) Kunt u aangeven welke methoden u gebruikt om ziekten en plagen te bestrijden? (*Waarom?*)

VIERDE SECTIE

1) Hoeveel bijeenkomsten (lezingen e.d.) over duurzame landbouw heeft u de afgelopen drie jaar bijgewoond?

2) Aan hoeveel projecten op gebied van duurzaam ondernemen heeft u de afgelopen drie jaar deelgenomen op vrijwillige basis? (bv. Projecten op het gebied van verminderd middelengebruik, verminderd nutriëntengebruik)

3) Wat heeft u de afgelopen drie jaar gedaan om de natuurlijke leefomgeving van bv. planten en vogels te verbeteren?

4) Wat heeft u de afgelopen drie jaar gedaan om de bodem- en waterkwaliteit te verbeteren?

Appendix III. NVIVO 9

We used NVivo in order to organize, analyze, and visualize the information contained in the written protocols. NVivo does not prescribe an analysis but provides the tools to analyze the data according to the methodological tools that we had. For example, since we had many sources and a large dataset sources we used the auto coding and query-based coding features. Nvivo uses its "own" language in order to organize the data and to support the analysis. There are three main concepts that we had to define before starting the analysis.

Sources.- A source is the collective term for the research materials—anything from 'primary' materials such as documents, videos or survey results. In our study, our sources were each one of the knowledge elicitation instruments.

Nodes.- A node is a collection of references about a specific theme, place, person or other area of interest. The references can be gathered by 'coding' sources such as interviews, articles, or survey results. In our study, while exploring the knowledge elicitation instrument, we coded the information in the protocols related to "systemic quality level" at the node "systemic qualities." We also created nodes based on different farmer attributes such as age, education level, experience, and diversification.

Codes.- Coding sources is a way of gathering all the references to a specific topic, theme, person or other entity. As mentioned while explained the nodes, we gathered systemic qualities in a node.

Queries.- Queries provide a flexible way to gather and explore subsets of your data. We created queries in order to find and analyze the words or phrases in the instrument. We also formulated hypotheses based on age, education, expertise, and diversification. We found patterns based on our coding.

Following we present the following reports

- Project summary.- Lists all the items within the project;
- Coding summary.- Lists the sources and the nodes that code them;
- Node summary.- Lists the nodes in the project including some information about each node;
- Queries summary.- Lists the queries that were executed during the analysis.

Project Summary

Cognitive Approach to Sustainable Agriculture

Hierarchical Name	Item Type	Created By Username	Created On	Modified By Username	Modified On
C:\Users\Huya\Desktop					
	Analysis of the dynamic knowledge structure of the 80 farmers that were interviewed for the study.				
Extracts					
Extracts\\Coding Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Node Classification Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Node Structure Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Node Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Project Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Source Classification Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Extracts\\Source Summary Extract	Extract	Jesus	18/10/2011 03:38 p.m.	Jesus	18/10/2011 03:38 p.m.
Sources					
Internals\\Interviews					
Internals\\Interviews\\01_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	21/10/2011 10:09 p.m.
Internals\\Interviews\\02_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	21/10/2011 10:13 p.m.
Internals\\Interviews\\03_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 04:55 p.m.

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12/01/2012 07:16 p.m.

Hierarchical Name	Item Type	Created By Username	Created On	Modified By Username	Modified On
Internals\\Interviews\\04_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:00 p.m.
Internals\\Interviews\\05_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	22/10/2011 11:59 a.m.
Internals\\Interviews\\06_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	22/10/2011 12:07 p.m.
Internals\\Interviews\\07_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:05 p.m.
Internals\\Interviews\\08_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	22/10/2011 12:35 p.m.
Internals\\Interviews\\09_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:11 p.m.
Internals\\Interviews\\10_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:11 p.m.
Internals\\Interviews\\11_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:14 p.m.
Internals\\Interviews\\12_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:17 p.m.
Internals\\Interviews\\13_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	22/10/2011 01:35 p.m.
Internals\\Interviews\\14_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:30 p.m.
Internals\\Interviews\\15_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:30 p.m.
Internals\\Interviews\\16_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:22 p.m.
Internals\\Interviews\\17_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:35 p.m.
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Internals\\Interviews\\19_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:38 p.m.
Internals\\Interviews\\20_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 05:40 p.m.
Internals\\Interviews\\21_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 03:44 p.m.
Internals\\Interviews\\22_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 11:39 a.m.
Internals\\Interviews\\23_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 11:49 a.m.
Internals\\Interviews\\24_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 11:57 a.m.
Internals\\Interviews\\25_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 10:51 a.m.
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Internals\\Interviews\\27_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 12:14 p.m.
Internals\\Interviews\\28_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 10:53 a.m.
Internals\\Interviews\\29_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 12:19 p.m.
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Internals\\Interviews\\33_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 12:40 p.m.
Internals\\Interviews\\34_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 12:48 p.m.
Internals\\Interviews\\35_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	24/10/2011 11:05 a.m.
Internals\\Interviews\\36_FA	Document	Huya	21/10/2011 05:31 p.m.	Huya	23/10/2011 12:59 p.m.

Internals\\Interviews\\37_FA	Document	Huya	21/10/2011 05:31	Huya	23/10/2011 01:03 p.m.
Internals\\Interviews\\38_FA	Document	Huya	21/10/2011 05:31	Huya	23/10/2011 01:10 p.m.
Internals\\Interviews\\39_FA	Document	Huya	21/10/2011 05:31	Huya	23/10/2011 01:15 p.m.
Internals\\Interviews\\40_FA	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:08 a.m.
Internals\\Interviews\\41_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:13 a.m.
Internals\\Interviews\\42_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:19 a.m.
Internals\\Interviews\\43_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:31 a.m.
Internals\\Interviews\\44_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:37 a.m.
Internals\\Interviews\\45_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 11:49 a.m.

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12/01/2012 07:16 p.m.

Hierarchical Name	**Item Type**	**Created By Username**	**Created On**	**Modified By Username**	**Modified On**
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Internals\\Interviews\\47_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:02 p.m.
Internals\\Interviews\\48_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:07 p.m.
Internals\\Interviews\\49_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:15 p.m.
Internals\\Interviews\\50_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:23 p.m.
Internals\\Interviews\\51_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:33 p.m.
Internals\\Interviews\\52_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:39 p.m.
Internals\\Interviews\\53_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 12:45 p.m.
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Internals\\Interviews\\57_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 01:13 p.m.
Internals\\Interviews\\58_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 01:18 p.m.
Internals\\Interviews\\59_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 01:26 p.m.
Internals\\Interviews\\60_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 01:31 p.m.
Internals\\Interviews\\61_FJ	Document	Huya	21/10/2011 05:31	Huya	24/10/2011 01:36 p.m.
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Nodes\\Systemic Thinking Qualities					
Nodes\\Systemic Thinking Qualities\\Cooperation	Node	Jesus	18/10/2011 04:03 p.m.	Huya	23/10/2011 05:53 p.m.
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Nodes\\Systemic Thinking Qualities\\Cooperation\L2C	Node	Huya	21/10/2011 05:34 p.m.	Huya	24/10/2011 05:38 p.m.
Nodes\\Systemic Thinking Qualities\\Cooperation\L3C	Node	Huya	21/10/2011 05:35 p.m.	Huya	25/10/2011 05:00 p.m.
Nodes\\Systemic Thinking Qualities\\Cooperation\L4C	Node	Huya	21/10/2011 05:36 p.m.	Huya	24/10/2011 05:25 p.m.
Nodes\\Systemic Thinking Qualities\\Feedback	Node	Jesus	18/10/2011 04:03 p.m.	Huya	23/10/2011 05:52 p.m.
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Nodes\\Systemic Thinking Qualities\\Feedback\L3F	Node	Huya	21/10/2011 05:40 p.m.	Huya	24/10/2011 05:28 p.m.
Nodes\\Systemic Thinking Qualities\\Feedback\L4F	Node	Huya	21/10/2011 05:42 p.m.	Huya	23/10/2011 11:41 a.m.
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Nodes\\Systemic Thinking Qualities\\Holism\L2H	Node	Huya	21/10/2011 05:43 p.m.	Huya	24/10/2011 05:14 p.m.
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Nodes\\Systemic Thinking Qualities\\Holism\L4H	Node	Huya	21/10/2011 05:45 p.m.	Huya	24/10/2011 05:21 p.m.
Nodes\\Systemic Thinking Qualities\\Interconnections	Node	Jesus	18/10/2011 04:02 p.m.	Huya	23/10/2011 05:53 p.m.

Nodes\\Systemic Thinking Qualities\\Interconnections\L1I	Node	Huya	21/10/2011 05:47 p.m.	Huya	24/10/2011 03:02 p.m.
Nodes\\Systemic Thinking Qualities\\Interconnections\L2I	Node	Huya	21/10/2011 05:49 p.m.	Huya	24/10/2011 05:40 p.m.
Nodes\\Systemic Thinking Qualities\\Interconnections\L3I	Node	Huya	21/10/2011 05:49 p.m.	Huya	24/10/2011 05:28 p.m.
Nodes\\Systemic Thinking Qualities\\Interconnections\L4I	Node	Huya	21/10/2011 05:50 p.m.	Huya	24/10/2011 05:34 p.m.

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12/01/2012 07:16 p.m.

Hierarchical Name	Item Type	Created By Username	Created On	Modified By Username	Modified On
Nodes\\Systemic Thinking Qualities\\Time Horizon	Node	Jesus	18/10/2011 04:02 p.m.	Huya	23/10/2011 05:53 p.m.
Nodes\\Systemic Thinking Qualities\\Time Horizon\L1TH	Node	Huya	21/10/2011 05:52 p.m.	Huya	24/10/2011 05:40 p.m.
Nodes\\Systemic Thinking Qualities\\Time Horizon\L2TH	Node	Huya	21/10/2011 05:53 p.m.	Huya	24/10/2011 05:19 p.m.
Nodes\\Systemic Thinking Qualities\\Time Horizon\L3TH	Node	Huya	21/10/2011 05:54 p.m.	Huya	24/10/2011 05:20 p.m.
Nodes\\Systemic Thinking Qualities\\Time Horizon\L4TH	Node	Huya	21/10/2011 05:55 p.m.	Huya	24/10/2011 04:42 p.m.

Queries

Queries\\Age Groups vs LEVELS of Systemic Qualities	Query	Huya	24/10/2011 06:33 p.m.	Huya	24/10/2011 06:33 p.m.
Queries\\Ind Var vs LEVELS of SQ	Query	Huya	24/10/2011 07:33 p.m.	Huya	24/10/2011 07:33 p.m.
Queries\\Independent Variables vs Systemic Qualities	Query	Huya	24/10/2011 06:18 p.m.	Huya	24/10/2011 06:18 p.m.
Queries\\Veldleeuwerik vs LEVELS of SQ	Query	Huya	24/10/2011 08:16 p.m.	Huya	24/10/2011 08:16 p.m.
Queries\\VL that scored almost always SQ L4	Query	Huya	06/12/2011 12:29 p.m.	Huya	06/12/2011 12:29 p.m.
Queries\\WF Diversification High	Query	Huya	25/10/2011 01:20 a.m.	Huya	25/10/2011 01:20 a.m.
Queries\\WF DiversificationLow	Query	Huya	25/10/2011 01:18 a.m.	Huya	25/10/2011 01:18 a.m.
Queries\\WF Education Level Basic	Query	Huya	25/10/2011 01:08 a.m.	Huya	25/10/2011 06:18 p.m.
Queries\\WF Education Level High	Query	Huya	25/10/2011 01:12 a.m.	Huya	25/10/2011 06:18 p.m.
Queries\\WF Expertise High	Query	Huya	25/10/2011 12:47 a.m.	Huya	25/10/2011 05:36 p.m.
Queries\\WF Expertise Low	Query	Huya	25/10/2011 12:53 a.m.	Huya	25/10/2011 05:37 p.m.
Queries\\WF Extra Activities Abscence	Query	Huya	25/10/2011 01:27 a.m.	Huya	25/10/2011 01:27 a.m.
Queries\\WF Extra Activities Presence	Query	Huya	25/10/2011 01:30 a.m.	Huya	25/10/2011 01:30 a.m.
Queries\\WF Non Veldleeuwerik	Query	Huya	24/10/2011 08:40 p.m.	Huya	25/10/2011 06:42 p.m.
Queries\\WF Old	Query	Huya	25/10/2011 12:42 a.m.	Huya	25/10/2011 12:42 a.m.
Queries\\WF Veldleeuwerik	Query	Huya	24/10/2011 09:11 p.m.	Huya	25/10/2011 06:42 p.m.
Queries\\WF Young	Query	Huya	25/10/2011 12:45 a.m.	Huya	25/10/2011 12:45 a.m.

Node Classification Summary

Cognitive Approach to Sustainable Agriculture

Attribute Value	Attribute Value Description	Number of Nodes Assigned
Attribute Name:	**DIVERSIFICATION (Low-High)**	
High		25
Low		55
Attribute Name:	**Education Level (Basic - University)**	
Basic		53
High		27
Attribute Name:	**Expertise (Low-High)**	
High		46
Low		34
Attribute Name:	**EXTRA OCCUPATIONAL ACTIVITIES**	
Absence		45
Presence		35
Attribute Name:	**Participation on Sustainable Project**	
NV		63
Veldleeuwerik		17
Attribute Name:	**Young/Old**	
Old		65
Attribute Value	**Attribute Value Description**	**Number of Nodes Assigned**
Young		15

SYSTEMIC QUALITIES

Name	*Levels*	*Sources*	*References*	*Created On*	*Created By*
Cooperation		73	101	18/10/2011 04:03 PM	JRC
	L1C	21	23	21/10/2011 05:33 PM	
	L2C	21	25	21/10/2011 05:34 PM	
	L3C	30	33	21/10/2011 05:35 PM	
	L4C	12	20	21/10/2011 05:36 PM	
Feedback		75	116	18/10/2011 04:03 PM	JRC
	L1F	6	6	21/10/2011 05:37 PM	
	L2F	41	49	21/10/2011 05:38 PM	
	L3F	42	59	21/10/2011 05:40 PM	
	L4F	1	2	21/10/2011 05:42 PM	
Holism		78	114	18/10/2011 04:01 PM	JRC
	L1H	1	1	21/10/2011 05:42 PM	
	L2H	18	22	21/10/2011 05:43 PM	
	L3H	40	49	21/10/2011 05:44 PM	
	L4H	33	42	21/10/2011 05:45 PM	
Interconnections		79	144	18/10/2011 04:02 PM	JRC
	L1I	2	2	21/10/2011 05:47 PM	
	L2I	46	74	21/10/2011 05:49 PM	
	L3I	47	60	21/10/2011 05:49 PM	
	L4I	7	8	21/10/2011 05:50 PM	
Time Horizon		75	93	18/10/2011 04:02 PM	JRC
	L1TH	36	39	21/10/2011 05:52 PM	
	L2TH	9	10	21/10/2011 05:53 PM	
	L3TH	7	7	21/10/2011 05:54 PM	
	L4TH	25	37	21/10/2011 05:55 PM	

[redacted]

Coding Summary

Cognitive Approach to Sustainable Agriculture

Hierarchical Name	Aggregate	Coverag e	Number Of Coding References	Number Of Users Coding
Document				
Internals\\Interviews\\01_FA				
Node				
Nodes\\Systemic Thinking Qualities\\Feedback	Yes	24.43 %	0	1
Nodes\\Systemic Thinking Qualities\\Feedback\L2F	No	21.48 %	4	1
Nodes\\Systemic Thinking Qualities\\Feedback\L3F	No	2.95 %	1	1
Nodes\\Systemic Thinking Qualities\\Holism	Yes	11.48 %	0	1
Nodes\\Systemic Thinking Qualities\\Holism\L3H	No	11.48 %	2	1
Nodes\\Systemic Thinking Qualities\\Interconnections	Yes	6.17 %	0	1
Nodes\\Systemic Thinking Qualities\\Interconnections\L2I	No	1.49 %	1	1
Nodes\\Systemic Thinking Qualities\\Interconnections\L3I	No	4.67 %	1	1
Nodes\\Systemic Thinking Qualities\\Time Horizon	Yes	6.94 %	0	1
Nodes\\Systemic Thinking Qualities\\Time Horizon\L4TH	No	6.94 %	1	1
INTERVIEWEE				
Nodes\\People\\01_FA	No	100.00 %	1	1

QUERIES

	Queries	Created On	Created By
	Age Groups vs LEVELS of Systemic Qualities	24/10/2011 06:33 PM	JRC
	Ind Var vs LEVELS of SQ	24/10/2011 07:34 PM	JRC
	Independent Variables vs Systemic Qualities	24/10/2011 06:18 PM	JRC
	Veldleeuwerik vs LEVELS of SQ	24/10/2011 08:16 PM	JRC
	VL that scored almost always SQ L4	06/12/2011 12:29 PM	JRC
	WF Diversification High	25/10/2011 01:20 AM	JRC
	WF DiversificationLow	25/10/2011 01:18 AM	JRC
	WF Education Level Basic	25/10/2011 01:08 AM	JRC
	WF Education Level High	25/10/2011 01:12 AM	JRC
	WF Expertise High	25/10/2011 12:47 AM	JRC
	WF Expertise Low	25/10/2011 12:53 AM	JRC
	WF Extra Activities Abscence	25/10/2011 01:27 AM	JRC
	WF Extra Activities Presence	25/10/2011 01:30 AM	JRC
	WF Non Veldleeuwerik	24/10/2011 08:40 PM	JRC
	WF Old	25/10/2011 12:42 AM	JRC
	WF Veldleeuwerik	24/10/2011 09:11 PM	JRC
	WF Young	25/10/2011 12:45 AM	JRC

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ENGLISH SUMMARY

The agricultural Dutch sector is facing a major challenge, which is the transition towards a sustainable agriculture. This sector is facing major changes, which can affect their entrepreneurial farming activities. The discussion thus far has been at a conceptual, especially macro level. A more deep approach to sustainability involves examining who is using "sustainability", and how. For example, how does sustainability operate at the farm level? This thesis engages with this question through exploration of three themes: Agriculture, Sustainability and Knowledge. This thesis aims at contributing to rethinking the role of farmers with regard to knowledge in achieving sustainability goals within agriculture.

As a first step we situate our study in the context of agriculture. We did a brief overview of the history of agriculture and we found that the massive application of modern agricultural techniques resulted in numerous ecological and societal problems. For example, modern agricultural technologies have masked the soil deterioration by increasing yields even as the soil has become degraded. Besides, the industrialization process along with the strengthening of large and globally networked agri-business and the commercialization of agricultural production practices resulted in the rise of corporate involvement, which has increased opportunities for larger economically buoyant farm holdings while at the same time reducing opportunities for small and economically struggling farm family based units.

This thesis combines agriculture with sustainability. For that reason attention is given to several meanings of sustainability. This research argues that there is not one way of viewing sustainability. Various understandings can be united under the umbrella of sustainability such as an ideology, a negotiation, a vision, a norm, an innovation or as a heuristic. This suggests that a key approach towards sustainability is the view that it should not be conceived of as a single concept, or even a consistent set of practices. When recognizing that sustainability is an unclear concept that derives its meaning from a specific context with the involvement of multiple stakeholders and disciplines, a question is raised as how to cope with these. We think that the response to this can be understood by a disciplinary study of sustainable agriculture.

The (mono and multi) disciplinary exercises have been important (Mebratu, 1998), because: 1) they can expand the knowledge base about the different aspects of the agricultural system and 2) they can open up a research agenda for the (natural and behavioral) sciences that encompass the study of agricultural system. To the extent that this consideration succeeds, it evolves towards interdisciplinarity. That is when different approaches are merged together and neatly integrated. Practicing interdisciplinarity, however, is also challenging. The interdisciplinary response is the current dominant approach to sustainability issues. One example of such approach is the "Triple Bottom Line or 3P" (people, planet and profit) concept coined by Elkington (1994). Managing

for a triple bottom line, suggests managing a balance between the economic, environmental, and social dimensions of business performance, rather than maximizing profits or growth. Triple bottom line recognizes from a "Planet" perspective, that focusing on this aspect of sustainable agriculture leads to maintaining or improving current levels of biophysical productivity. From a "Profit" perspective, agriculture is an enterprise at the farm level and an important economic sector on the international, regional, national, and local levels. From a "People" perspective, sustainable agriculture is associated with the prospects of meeting national and global food needs, well-being of people (individually and socially) and human development in a general sense. As a complement to multi and interdisciplinary, transdisciplinarity signifies the crossing of boundaries between scientific and non-scientific communities. Transdisciplinarity represents a set of interactions between the scientists and representatives of industry, government, or civil society (Schoot Uiterkamp and Vlek, 2007; Jorna, 2006). This may deepen society's understanding (as a whole) of complex problems –such as how to transit towards sustainability- and may prevent the selection of too limited or biased solutions. We found that systems theory and systems thinking provide a framework to talk about (and represent) complexity and change (Chen and Stroup, 1993; Martin, 2002). The central concept of systems theory is to understand how parts in a system interact and to seek underlying systemic interrelationships. This means that instead of isolating smaller parts of the system being studied, systems thinking works by expanding its view to take into account larger numbers of interaction.

We observed that in general, the different views on sustainability do not recognize (individual) knowledge as an explicit factor, although it encompasses understandings (or mental models) of sustainability. Knowledge representations of sustainability with farmers are often forgotten. We make explicit the recognition of (individual) knowledge as driver for sustainability. The study supports the HIP (Human Information Processing) hypothesis of Newell and Simon (1972). The theoretical framework was information processing as an attempt to explain all behavior as a function of memory operations, control processes and representational rules. This asks for a bottom-up approach, meaning an approach starting from the individual interpretation of the agricultural context. Farmers use perceptions, the meanings of words and sentences and the significances of propositions they express as knowledge. Farmers represent this in a mental model of the world. The conclusions farmers draw depend on the (mental) models they hold. In any case, at the heart of reasoning are mental representations. This means that farmers need knowledge content of various aspects of sustainable agriculture. This in turn implies that farmers need processes to acquire and incorporate knowledge into their practices. In other words, the knowledge that a farmer possesses can be distinguished in terms of (domain) content and (reasoning) processes.

The distinction between knowledge in terms of content and processes forms the basis of two key concepts in our research: Knowledge of Sustainability (KoS) and Sustainability of Knowledge (SoK), (Jorna, 2006; 2010). KoS indicates 1) The knowledge content about the actual state of agriculture and causes that underlie environmental, social, and individual problems, and 2) The knowledge by which such problems can be resolved. On the other hand, SoK focuses on knowledge, learning, organizational and agricultural processes that govern production, creation, use and integration of knowledge. With KoS as a background we built a conceptual model in chapter 5 where we aimed at identifying concepts linked with sustainable agriculture (knowledge static aspects) and to get some insights in the way of reasoning among the farmers (knowledge dynamic aspects). We argue that research and development effort in agriculture are dependent on the farmer's knowledge structure.

Given the current state of knowledge of sustainability, two needs were identified. First, there is a lack of operational detail regarding the knowledge aspects to understand sustainable agriculture. A systems approach provides an overview and manner of understanding how the different relationships in a specific context work. Based on system's theory we presented five systemic qualities (based on assignments made by farmers) that can be used to distinguish a sustainable oriented knowledge structure from the knowledge structure of classical farming. First, we have the systemic quality of the integration of the system. Systems are frequently so complex that their behavior cannot be deduced from the properties of the elements alone. The components of the agricultural system discussed in chapter 2 function together as a whole and not independently. As a second systemic quality, we have the focus on interconnections. The interactions of the elements within the agricultural system operate together as a set of interdependent relationships (Richmond, 2005). The third systemic quality focuses on feedback loops. Feedback describes a closed chain of causal connections (Meadows, 2008). For example, the more soil is eroded, the fewer plants are able to grow, so the fewer roots that can hold the soil, so the more soil erodes, so less plants can grow. Cooperation is the fourth systemic quality. Cooperation is the process by which the actors in a system work together to achieve global properties. Cooperation among farmers can be important because a group has more knowledge than an individual. Last, we have a time perspective. The impacts due to disturbances within the system become less predictable over time. Soil erosion, for example, can proceed for a long time without farmers realizing this (if they only focus on the effect on crop yield) until the topsoil is exhausted to the depth of the root zone of the crop. Beyond that point, erosion can cause yields to decrease.

The second need was to understand the knowledge structure of the different stakeholders involved in the agricultural system, starting with the main actors, the farmers. Structuring of knowledge and reasoning in the agricultural system involves deciding what to do. Apart from the static elements of knowledge, chapter 7 deals with the dynamic elements of knowledge, the reasoning patterns of farmers. The reasoning patterns are relative to the manner in which farmers think and reason about sustainable agricultural issues. Therefore we developed an instrument to elicit the static and the dynamic aspects of knowledge. The instrument consisted of four parts. The first part was a questionnaire about the participant's background. In the second part cognitive maps were realized by individual farmers. The maps consisted of concepts that the farmer considered while making a sowing plan. It concerns cognitive maps "built" and elicited by the participants. The concepts included in the cognitive maps were classified according of the three themes of the Triple Bottom Line approach (Planet, Profit and People). The most chosen concepts for Planet related to the topic of soil (such as soil structure and sowing plan). All the concepts included in Profit were relevant in building the cognitive maps. The most chosen concepts for People was customer opinion. In general, concepts included in People were used with lower frequency. The third part gauged the systemic qualities of a farmer's thinking through verbal protocols obtained by solving assignments specifically developed for the study. The last part consisted of a series of open questions.

This study focused on individual farmers, particularly on the knowledge they have and use regarding sustainable agriculture and the way in which farmers structure that knowledge. The sample for this study was derived from a database of arable farmers, which are customers of BLGG AgroXpertus from all over the Netherlands but especially from the following regions: Flevoland, Groningen, Noord Brabant and Zeeland.

In our work, systems' thinking refers to a special vocabulary with which farmers expressed their understanding of the dynamic complexity within agriculture. For example, systems thinkers often describe the world in terms of time horizons, interconnections, feedback, and cooperation. The results regarding the age of farmers suggest that old farmers focus more on long-term events while young farmers focus in their present situation.

We present a summary of the following important findings,

- Higher educated farmers include more KoS concepts that can be classified within the "Profit" category than lower educated farmers;
- Higher educated farmers include more "Long Time Horizon" references in their protocols than less educated farmers do;
- The more diversified the farmer the more complex the cognitive map;
- The more diversified the farmer the more "Integration" references included in the protocol´s profile;
- The older farmers show a larger number of "Profit" concepts within their cognitive maps.

In concluding, it is important to note that a knowledge perspective should be viewed as complementary, rather than incompatible with, other points of view in the study of sustainable agriculture—perspectives deriving from economics, organizational strategy, sociology or environmental sciences. The instrument we developed can be used to increase understanding and communication about situations in both the short term and long term, looking at the details and the ways in how the different aspects of the agricultural system are integrated. All that is being suggested here is that the cognitive perspective may provide necessary insights into the complex process of farming over and above those offered by the other points of view. Any perspective that offers the promise of both scientific progress and practical interventions would seem worthy of very careful attention indeed. However, there is no guarantee that such efforts will succeed—since there are never any guarantees in scientific research. Nevertheless, we believe that aiming at making this world a better planet to live for us, for those who lack a descent quality of life, and for the future generations is well worthwhile the attempt. We believe that a knowledge view towards sustainable agriculture can lead to creative solutions to these complex challenges.

NEDERLANDSE SAMENVATTING

De agrarische sector in Nederland staat voor de uitdaging om de landbouw te verduurzamen. De sector heeft te maken met grote veranderingen die invloed hebben op de agrarische ondernemersactiviteiten. Tot nu heeft de discussie hieromtrent plaats gehad op een conceptueel niveau, in het bijzonder macroniveau. Een meer diepgaande benadering van duurzaamheid omvat wie "duurzaamheid" gebruikt en hoe. Bijvoorbeeld, wat duurzaamheid concreet betekent op het niveau van het landbouwbedrijf. Dit proefschrift houdt zich bezig met deze vraag middels de verkenning van drie thema's: landbouw, duurzaamheid en kennis. Dit proefschrift heeft als doel om bij te dragen aan de discussie over de rol van boeren met betrekking tot kennis voor het bereiken van duurzaamheidsdoelstellingen in de landbouw.

Als eerste stap situeren we ons onderzoek in de context van de landbouw. We hebben een kort overzicht van de geschiedenis van de landbouw beschreven en we vonden dat de massale toepassing van moderne landbouwtechnieken resulteerde in tal van ecologische en maatschappelijke problemen. Moderne landbouwtechnieken die resulteren in hogere productiviteit verhullen bijvoorbeeld de uitputting van de bodem. Bovendien heeft het proces van industrialisatie samen met de almaar groter wordende agribusiness en de vercommercialisering van agrarische productiemethoden geresulteerd in de betrokkenheid van het grote bedrijfsleven. Dit heeft geresulteerd in toenemende mogelijkheden voor grotere economisch florerende boerenbedrijven, terwijl tegelijkertijd mogelijkheden voor kleine boerenbedrijven die het economisch zwaar hebben en gerund worden door een familie verminderen.

Dit proefschrift combineert landbouw met duurzaamheid. Om die reden besteden we aandacht aan verschillende betekenissen van het woord duurzaamheid. Dit onderzoek stelt dat er niet slechts één manier van kijken naar duurzaamheid is. Duurzaamheid omvat ideologie, onderhandeling, een visie, een norm, een innovatie of een heuristiek. Dit suggereert dat het belangrijk is duurzaamheid niet als één concept op te vatten, of zelfs een consistente set van praktijken. Wanneer erkend wordt dat duurzaamheid een onduidelijk concept is dat zijn mening ontleend aan de context met verschillende belanghebbenden en disciplines, dan rijst de vraag hoe hier mee om te gaan. Wij denken dat het antwoord op deze vraag begrepen kan worden middels een disciplinaire studie naar duurzame landbouw.

De (mono- en multi) disciplinaire benaderingen zijn belangrijk (Mebratu, 1998), 1) omdat ze de kennis van verschillende aspecten van het landbouwsysteem kunnen vergroten en 2) omdat ze een onderzoeksagenda kunnen identificeren voor de (natuur- en gedrags-) wetenschappen die de studie van landbouwsystemen omvat. In de mate waarin deze overweging slaagt, evolueert het tot interdisciplinariteit. Dat houdt in dat verschillende benaderingen worden samengevoegd en nauw worden geïntegreerd. Echter, in de praktijk kan interdisciplinariteit ook moeilijk zijn. De interdisciplinaire reactie is de huidige dominante benadering van duurzaamheid. Één voorbeeld van een dergelijke benadering is het "Triple Bottom Line of 3P" (people, planet, profit) concept van Elkington (1994). Het beheren van een Triple Bottom Line suggereert het balanceren van economische, ecologische en sociale aspecten van bedrijfsprestaties, in plaats van het maximaliseren van winst of groei alleen. Het Triple Bottom Line concept herkent vanuit een "Planet" perspectief dat focussen op dit aspect van duurzame landbouw leidt tot behoud en verbetering van huidige niveaus van biofysische productiviteit. Vanuit een "Profit" perspectief wordt landbouw gezien als een onderneming op het niveau van het boerenbedrijf en een belangrijke economische sector op internationaal, regionaal, nationaal en lokaal niveau. Vanuit een "People" perspectief wordt duurzame landbouw geassocieerd met de vooruitzichten om in nationale en globale voedselbehoeften te voorzien, het welzijn van mensen (individueel en sociaal) en menselijke ontwikkeling in een algemene zin. Als aanvulling op de multi- en interdisciplinariteit, betekent transdisciplinariteit de overschrijding van de grenzen tussen wetenschappelijke en niet-wetenschappelijke gemeenschappen. Transdisciplinariteit staat voor een reeks van interacties tussen de wetenschappers en vertegenwoordigers van de industrie, overheid, of het maatschappelijk middenveld (Schoot Uiterkamp en Vlek, 2007; Jorna, 2006). Dit kan leiden tot een verdiepend maatschappelijk begrip (als geheel) van complexe problemen – zoals hoe te verduurzamen- en kan beperkte of eenzijdige oplossingen beperken. Wij vonden dat systeemtheorie en systeemdenken een kader kan bieden om te praten over de complexiteit en verandering en deze te vertegenwoordigen (Chen en Stroup, 1993; Martin, 2002). Het centrale concept van de systeemtheorie gaat om het begrijpen van hoe delen in een systeem samenwerken en om het vinden van onderliggende systematische verbanden. Dit betekent dat systeemdenken bij haar benadering rekening houdt met grotere aantallen verbanden dan wanneer kleine delen van het gehele systeem afzonderlijk worden bestudeerd.

We hebben waargenomen dat de verschillende visies op duurzaamheid (individuele) kennis niet erkennen als een expliciete factor, hoewel het begrippen (of mentale modellen) van duurzaamheid omvat. Kennis voorstellingen van duurzaamheid van de boeren worden vaak vergeten. Wij maken expliciet de erkenning van de (individuele) kennis als motor voor duurzaamheid. De studie ondersteunt de HIP (Human Information Processing) hypothese van Newell en Simon (1972). Het theoretisch kader was de verwerking van informatie als een poging om alle gedrag uit te leggen als een functie van geheugen operaties, controle processen en representatieve regels. Dit vraagt om een bottom-up benadering, dat wil zeggen een aanpak uitgaande van de individuele interpretatie van de agrarische context. Boeren gebruiken percepties, de betekenis van woorden en zinnen en de betekenissen van geuite proposities als kennis. Boeren vangen dit in een mentaal model van de wereld. De conclusies die boeren trekken zijn afhankelijk van de (mentale) modellen die zij bezitten. Dit betekent dat landbouwers kennis inhoud van de verschillende aspecten van duurzame landbouw nodig hebben. Daardoor hebben boeren processen nodig om kennis te vergaren en toe te passen in dagelijkse werkzaamheden.

Met andere woorden, de kennis die een boer heeft kan onderscheiden worden op het gebied van (domein) inhoud en (redenering) processen.

Het onderscheid tussen kennis op het gebied van inhoud en processen vormt de basis van twee belangrijke concepten in ons onderzoek: Kennis van Duurzaamheid (KoS) en Duurzaamheid van Kennis (SoK), (Jorna, 2006; 2010). KoS betekent 1) De kennisinhoud over de huidige stand van de landbouw en de oorzaken die aan milieu, sociale en individuele problemen ten grondslag liggen, en 2) De kennis waarmee deze problemen kunnen worden opgelost. Aan de andere kant, SoK richt zich op kennis, leren, organisatorische en agrarische processen die de productie, ontwikkeling, toepassing en integratie van kennis regeren. Met KoS als achtergrond bouwden we een conceptueel model in hoofdstuk 5, gericht op het identificeren van concepten die verband houden met duurzame landbouw (kennis statische aspecten) en om enig inzicht te krijgen in de manier van redeneren onder de boeren (kennis dynamische aspecten). We stellen dat onderzoek en ontwikkeling in de landbouw afhankelijk zijn van de kennisstructuur van de boer.

Gezien de huidige stand van kennis over duurzaamheid, zij twee behoeften geïdentificeerd. Ten eerste is er een gebrek aan operationele details met betrekking tot aspecten van kennis om de duurzame landbouw te begrijpen. Een systeembenadering biedt een overzicht en manier om te begrijpen hoe de verschillende relaties in een specifieke context werken. Op basis van theorie systeem stelden wij vijf systemische eigenschappen (gebaseerd op opdrachten gemaakt door de boeren) die gebruikt kunnen worden om een op duurzaamheid gerichte kennisstructuur te onderscheiden van de kennis structuur van de klassieke landbouw. Ten eerste hebben we de systemische kwaliteit van de integratie van het systeem. Systemen zijn vaak zo complex dat hun gedrag niet kan worden afgeleid uit de eigenschappen van de elementen alleen. De componenten van het landbouwsysteem besproken in hoofdstuk 2 werken als een geheel samen en zijn niet onafhankelijk van elkaar. Als tweede systemische kwaliteit hebben we de focus op interconnecties. De interacties van de elementen binnen het landbouwsysteem werken als een stelsel van onderling afhankelijke relaties samen (Richmond, 2005). De derde systemische kwaliteit richt zich op feedback loops. Terugkoppeling beschrijft een gesloten keten van causale verbanden (Meadows, 2008). Bijvoorbeeld, hoe meer grond wordt geërodeerd hoe minder planten kunnen groeien, zodat minder wortels de bodem houden, zodat meer bodem erodeert, zodat minder planten kunnen groeien. Samenwerking is de vierde systemische kwaliteit. Samenwerking is het proces waarbij de acteurs in een systeem samenwerken om algemene eigenschappen te verkrijgen. Samenwerking tussen boeren kan belangrijk zijn omdat een groep heeft meer kennis dan een individu. Tot slot hebben we een tijdsperspectief. De effecten als gevolg van storingen in het systeem worden minder voorspelbaar met het verloop van tijd. Bodemerosie, bijvoorbeeld, kan gedurende lange tijd plaatsvinden zonder dat boeren dit zich realiseren van deze (als ze richten zich op het effect op de gewasopbrengst) tot de bovengrond is uitgeput tot aan de diepte van de wortelzone van het gewas. Nadien kan erosie leiden tot minder opbrengsten.

De tweede behoefte was om de kennisstructuur van de verschillende partijen die betrokken zijn in het agrarische systeem te begrijpen, te beginnen met de belangrijkste actoren, de boeren. Het structureren van kennis en redeneren in het landbouwsysteem behelst het nemen van beslissingen wat te doen. Naast de statische elementen van kennis gaat hoofdstuk 7 over de dynamische elementen van kennis, de redenering patronen van boeren. De redenering patronen zijn relatief ten opzichte van de wijze waarop boeren denken en redeneren over duurzame landbouw kwesties. Daarom hebben we een instrument ontwikkeld om de statische en de dynamische aspecten van kennis. Het instrument bestond uit vier onderdelen te achterhalen. Het eerste deel was een vragenlijst over de achtergrond van de deelnemer. In het tweede deel werden cognitie kaarten gerealiseerd door individuele boeren. De kaarten bestonden uit concepten die de boer beschouwde tijdens het maken van een zaai plan. De concepten die opgenomen zijn in de cognitieve kaarten werden ingedeeld op basis van de drie thema's van de Triple Bottom Line (Planet, Profit en People). De meest gekozen concepten voor “Planet” zijn gerelateerd aan het onderwerp bodem (zoals de bodemstructuur en het zaai plan). Alle concepten opgenomen in “Profit” waren relevant in het bouwen van de cognitie kaarten. De meest gekozen concepten voor “People” was klantadvies. In het algemeen, werden begrippen in “People” met een lagere frequentie gekozen. Het derde deel had tot doel de systemische kwaliteiten van het denken van boeren te meten door middel van verbale protocollen, verkregen door het oplossen van opdrachten speciaal ontwikkeld voor de studie. Het laatste gedeelte bestond uit een aantal open vragen.

Dit onderzoek richtte zich op individuele boeren en hun kennis en hun gebruik van deze kennis met betrekking tot duurzame landbouw. Ook kijk het onderzoek naar de manier waarop de boeren deze kennis structureren. De steekproef voor deze studie was afgeleid van een database van akkerbouwers, dit zijn klanten van Blgg AgroXpertus uit heel Nederland, maar vooral uit de volgende regio's: Flevoland, Groningen, Noord-Brabant en Zeeland.

In dit onderzoek verwijst systeemdenken naar een speciale woordenschat waarmee boeren hun interpretatie van de dynamische en complexe structuren binnen de landbouw uitdrukken. Bijvoorbeeld, systeemdenkers beschrijven de wereld vaak in termen van tijdperspectief, interconnecties, feedback en samenwerking. De resultaten met betrekking tot de leeftijd van boeren suggereren dat oude boeren zich meer richten op lange termijn gebeurtenissen, terwijl jonge boeren zich richten op de korte termijn.

Hier is een samenvatting van de opgenomen volgende belangrijke bevindingen:

• Hoger opgeleide boeren gebruiken meer KoS concepten die binnen de “Profit” categorie worden ingedeeld dan lager opgeleiden boeren;

• Hoger opgeleide boeren gebruiken vaker “Lange Tijdsperspectief” referenties in hun protocollen dan minder opgeleide boeren;

• Hoe meer gediversificeerd het boerenbedrijf hoe complexer de cognitiekaart van de boer;

• Hoe meer gediversificeerd het boerenbedrijf hoe meer “Integratie” referenties gebruikt in het profiel van het protocol;

• De oudere boeren gebruiken een groter aantal “Profit” concepten in hun cognitiekaarten.

Concluderend, een kennis-perspectief moet worden gezien als complementair, in plaats van onverenigbaar, met andere duurzame landbouw-perspectieven, die voortvloeien uit de economische, organisatorische, sociologische of milieuwetenschappen. Het door ons ontwikkelde instrument kan worden gebruikt om begrip van en de communicatie over situaties zowel op de korte termijn als de lange termijn te bevorderen naar manieren om verschillende aspecten van het landbouwsysteem te integreren. Wij laten zien dat het cognitieve perspectief nieuwe inzicht kan geven in het dynamische en complexe structuren van de landbouw. Dit perspectief, dat een basis is voor zowel wetenschappelijke vooruitgang als praktische interventies, is dan ook zorgvuldige aandachtwaard. Alhoewel het toepassen van dit perspectief geen garantie is voor succes, zijn wij van mening dat het streven naar een beter wereld voor de huidige en toekomstige generaties een poging hiertoe de moeite waard maakt. Een kennis perspectief op duurzame landbouw kan leiden tot creatieve oplossingen voor de complexe uitdagingen in deze sector.

RESUMEN EN ESPAÑOL

El sector agrícola holandés enfrenta un reto importante, la transición hacia una agricultura sostenible. Este sector se enfrenta a grandes cambios que pueden afectar sus actividades. La discusión hasta ahora ha sido a un nivel conceptual, sobre todo macro. Un enfoque más profundo implica examinar quién está utilizando la sostenibilidad, y cómo se está utilizando. Por ejemplo, ¿cómo opera la sostenibilidad a nivel del campo? En esta tesis se responde a esta interrogante a través de la exploración de tres temas: agricultura, sostenibilidad y gestión del conocimiento. Este trabajo contribuye a repensar el rol de los agricultores, teniendo como punto de partida el papel del contenido del conocimiento en la consecución de una agricultura sostenible.

Como primer paso, situamos nuestro estudio en el contexto de la agricultura. Se realizó una breve reseña de la historia de la agricultura y se ha encontrado que la aplicación masiva de técnicas agrícolas modernas dio lugar a numerosos problemas ecológicos y sociales. Por ejemplo, el uso de tecnologías agrícolas modernas ha propiciado que aun y cuando exista deterioro del suelo, éste sea minimizado al debido a un aumento en el rendimiento de los cultivos. Además, el proceso de industrialización, junto con el fortalecimiento de negocios agrícolas a gran escala así como empresas agrícolas con una presencia global, resultó en un incremento en la participación de empresas privadas en el sector agrícola. Este incremento ha propiciado mayores oportunidades para grandes empresas mientras que al mismo tiempo ha reducido las oportunidades para pequeñas empresas.

En esta tesis se combina la agricultura con la sostenibilidad. Por esa razón se presta atención a varias definiciones de sostenibilidad. Esta investigación sostiene que no hay una sola manera de entender la sostenibilidad. Varias interpretaciones están incluidas bajo el abanico de la sostenibilidad. Por ejemplo, la sostenibilidad puede ser entendida como una ideología, una negociación, una visión, una norma, una innovación o como una heurística. Esto sugiere que un enfoque clave para la sostenibilidad es la opinión de que no debe ser concebida como un solo concepto, o incluso como un conjunto de prácticas. Al reconocer que la sostenibilidad es un concepto poco claro que deriva de un contexto específico con la participación de múltiples actores y disciplinas, surge la pregunta de cómo hacer frente a esta situación. Creemos que la respuesta puede ser dada por un estudio disciplinario de la agricultura sostenible.

Los enfoques (mono y multi) disciplinarios han sido importantes (Mebratu, 1998), debido a que: 1) se puede ampliar la base de conocimiento referente a los distintos aspectos del sistema agrícola y 2) puede abrirse una agenda de investigación para las ciencias (naturales y del comportamiento) que abarcan el estudio de sistemas agrícolas. En la medida en que estos enfoques son exitosos, éstos evoluciona hacia la interdisciplinariedad. Es entonces cuando los diferentes enfoques se combinan entre sí y se integran perfectamente. La práctica de la interdisciplinariedad, sin embargo, es también un reto. La respuesta interdisciplinaria es el actual enfoque dominante para las cuestiones de sostenibilidad. Un ejemplo de este enfoque es la "Triple Bottom Line o 3P" (“Planet”, “People”, “Profit”) concepto acuñado por Elkington (1994). Gestionar con base en el “Tripple Bottom Line”, sugiere un equilibrio entre las dimensiones económica, ambiental y social de una empresa, en vez de –solo- maximizar las ganancias o el crecimiento económico. La dimensión de “Planet” que centrándose en este aspecto de la agricultura sostenible conduce a mantener o mejorar los actuales niveles de productividad biofísica. La dimensión “Profit”, la actividad agrícola es vista como una actividad empresarial y como un sector económico importante en los niveles internacional, regional, nacional y local. La dimensión “People, la agricultura sostenible es asociada con la meta de satisfacer las necesidades alimentarias nacionales y mundiales, y el desarrollo humano en un sentido general. Como complemento a lo multi e interdisciplinario, transdisciplinario significa el cruce de las fronteras entre las comunidades científicas y no científicas. La transdisciplinariedad representa interacciones entre los científicos y representantes de la industria, del gobierno o de la sociedad civil (Schoot Uiterkamp y Vlek, 2007; Jorna, 2006). Esto puede ayudar a la sociedad con la comprensión de problemas complejos tales como la transición hacia una agricultura sostenible, y puede evitar la selección de soluciones limitadas o incompletas. La teoría de sistemas proporciona un marco para estudiar la complejidad y el cambio (Chen y Stroup, 1993; Martin, 2002). El concepto central de la teoría de sistemas es comprender cómo interactúan las partes de un sistema así como buscar las interrelaciones sistémicas subyacentes. Esto significa que en vez de aislar las partes del sistema en estudio, el enfoque en sistemas favorece el tener en cuenta las interacciones entre todas las partes del sistema.

Los diferentes puntos de vista sobre la sostenibilidad no reconocen el conocimiento (del individuo) como un factor explícito, a pesar de que abarca la comprensión (modelos mentales) de la sostenibilidad. Las representaciones del contenido del conocimiento de los agricultores con respecto a la sostenibilidad a menudo son olvidadas. Hacemos explícito el reconocimiento el conocimiento (del individuo) como motor de la sostenibilidad. Este estudio apoya la hipótesis del ser humano como procesador de la información (HIP) de Newell y Simon (1972). El marco teórico es el procesamiento de la información como un intento de explicar el comportamiento humano en función de las operaciones de memoria, los procesos de control y las normas de representación. Para la aplicación de este marco teórico se necesita un enfoque “bottom-up”, es decir, un enfoque a partir de la interpretación individual del contexto agrícola. Los agricultores utilizan su percepción del mundo y los significados de palabras y frases como conocimiento. Los agricultores representan esto en modelos mentales y obtienen conclusiones basados éstos. Esto significa que los agricultores necesitan el contenido de conocimiento de diversos aspectos de la agricultura sostenible. Esto a su vez implica que los agricultores emplean procesos para adquirir e incorporar el conocimiento en sus prácticas. En otras palabras, el conocimiento que un agricultor posee se puede distinguir en términos de contenido (dominio) y procesos emntales (razonamiento).

La distinción en términos de contenido y de procesos mentales es la base de dos conceptos clave en nuestra investigación: El Conocimiento de la Sostenibilidad (KoS) y la Sostenibilidad del Conocimiento (SoK), (Jorna, 2006; 2010). “KoS” indica 1) El contenido de conocimiento sobre el estado actual de la agricultura y las causas que subyacen a los problemas ambientales, sociales e individuales, y 2) el conocimiento por el cual este tipo de problemas se pueden resolver. Por otro lado, “SoK” se centra en el aprendizaje, los procesos de organización que rigen la producción agrícola, así como la creación, uso e integración de conocimiento. Con “KoS” como concepto central hemos construido un modelo conceptual en el capítulo 5, donde el objetivo es identificar los conceptos relacionados con la agricultura sostenible (aspectos estáticos de conocimiento) y obtener algunas ideas en la forma de razonamiento entre los agricultores (aspectos dinámicos del conocimiento). La investigación y desarrollo en la agricultura dependen de la estructura de conocimiento de los agricultores.

Dado el estado actual del conocimiento sobre sostenibilidad, dos necesidades se identificaron en esta tesis. En primer lugar, hay una falta de detalles operativos en relación con los aspectos de conocimiento disponible para entender la agricultura sostenible. Con base en la teoría de sistemas presentamos cinco propiedades sistémicas que son utilizadas para hacer operativa la estructura de conocimiento de los agricultores. En primer lugar, tenemos la propiedad sistémica de Integración del sistema. Los sistemas son con frecuencia complejos y su comportamiento no se puede deducir de las propiedades de los elementos individuales que lo componen. Los componentes del sistema agrícola definidos en el capítulo 2 funcionan de manera conjunta y no de forma independiente. La segunda propiedad sistémica es el foco en las Interconexiones. Interconexiones se refiere a las interacciones entre los elementos que componen del sistema agrícola para que éste funcione como un conjunto de relaciones interdependientes (Richmond, 2005). La tercera propiedad sistémica se centra en los lazos de Retroalimentación. La retroalimentación describe una cadena cerrada de relaciones causales (Meadows, 2008). Por ejemplo, debido a la erosión del suelo menos plantas crecen, por lo tanto, el número de raíces que pueden contener el suelo son menores, por lo que el suelo se erosiona más, lo que a su vez ocasiona que crezcan menos plantas. Cooperación es la cuarta propiedad sistémica. Cooperación es el proceso mediante el cual los actores en un sistema trabajan juntos para lograr la operación global del sistema. La cooperación entre los agricultores puede ser importante debido a que un grupo tiene más conocimiento que un individuo. Por último, tenemos la propiedad sistémica que se refiere ala perspectiva de tiempo. Los efectos debidos a las alteraciones en el sistema cada vez menos previsible en el tiempo. La erosión del suelo, por ejemplo, puede existir durante mucho tiempo sin que los agricultores se percaten hasta que la capa superior del suelo se ha agotado. Más allá de ese punto, la erosión puede causar una disminución en el rendimiento de los cultivos.

La segunda necesidad fue comprender como estructuran el contenido del conocimiento los diferentes actores involucrados en el sistema agrícola, en especial la estructura de los actores principales, los agricultores. La estructuración del conocimiento y el razonamiento en el sistema agrícola influye en la toma de decisiones. Aparte de los elementos estáticos de conocimiento, el capítulo 7 se refiere a los elementos dinámicos, es decir, el razonamiento de los agricultores. Los patrones de razonamiento son relativos a la forma en que los agricultores de piensan y razonan acerca de las cuestiones agrícolas sostenibles. Por lo tanto, hemos desarrollado un instrumento para poder obtener los aspectos estáticos y dinámicos del conocimiento. El instrumento consto de cuatro partes. La primera parte fue un cuestionario empleado para conocer información demográfica de los participantes. En la segunda parte, mapas cognitivos fueron realizados por los agricultores de manera individual. Los conceptos contenidos en los mapas cognitivos son aquéllos que el agricultor considera al planear las actividades de siembra de su principal producto. Los conceptos incluidos en los mapas cognitivos fueron clasificados de acuerdo a las tres dimensiones del “Tripple Bottom Line”. Los conceptos elegidos con mayor frecuencia para la dimensión “Planet” fueron los relacionados con el tema del suelo (tales como la estructura y el plan de siembra). Todos los conceptos incluidos en la dimensión “Profit” fueron relevantes en la construcción de los mapas cognitivos. El concepto más utilizado de la dimensión “People” fue la “Opinión de los clientes”. En general, los conceptos incluidos en “People” se utilizaron con menor frecuencia. La tercera parte del instrumento indicaba las propiedades sistémicas del pensamiento de un agricultor a través de protocolos verbales (obtenidos durante la solución de tareas desarrolladas específicamente para este estudio). La última parte consistió en una serie de preguntas abiertas.

Este estudio se centró en agricultores individuales, en particular en el contenido del conocimiento sobre agricultura sostenible que ellos poseen. También se puso atención a la manera en como ese conocimiento es utilizado. La muestra para este estudio se elaboró a partir de una base de datos de productores clientes de BLGG AgroXpertus. Estos productores se localizan en las siguientes regiones: Flevoland, Groningen, Noord Brabant y Zeeland.

En el presente trabajo, el pensamiento sistémico hace referencia a un vocabulario especial con el que los agricultores expresaron su comprensión de la complejidad del sistema agrícola. Por ejemplo, los pensadores sistémicos a menudo describieron el mundo en términos de perspectiva del tiempo, interconexiones, retroalimentación y cooperación. Los resultados con respecto a la edad de los agricultores indican que los agricultores "viejos" se centran más en eventos a largo plazo, mientras que los agricultores "jóvenes" se centran en su situación actual.

A continuación se presenta un las conclusiones mas importantes:

• Agricultores con un nivel educativo alto incluyen más conceptos (KoS) de la dimensión "Profit" que agricultores con un nivel educativo bajo;

• Agricultores con un nivel educativo alto incluyen un mayor número de referencias de la propiedad sistémica "Perspectiva del tiempo" en sus protocolos en comparación con los agricultores con nivel educativo bajo;

• A mayor diversificación de la actividad agrícola mayor es la complejidad de los mapas cognitivos construidos por los agricultores;

• A mayor diversificación de la actividad agrícola mayor es el número de referencias de la propiedad sistémica "Integración" en los protocolos obtenidos;

• Los agricultores de mayor edad muestran un mayor número de conceptos relacionados con la dimensión "Profit" dentro de sus mapas cognitivos.

Para concluir esta tesis, es importante señalar que el enfoque proporcionado por la gestión del conocimiento debe verse como un enfoque complementario más que incompatible con otros puntos de vista en el estudio de la agricultura sostenible – puntos de vista que derivan de la economía, la estrategia organizacional, la sociología o las ciencias del medio ambiente. El instrumento que hemos desarrollado se puede utilizar para aumentar la comprensión y la comunicación acerca de situaciones, tanto en el corto como en el largo plazo; observando los detalles y la forma en cómo los diferentes aspectos del sistema agrícola se encuentran integrados. La perspectiva basada en la ciencia cognitiva puede proporcionar conocimiento complementario a la ofrecida por otras perspectivas. Cualquier enfoque que ofrece la promesa de progreso científico y de intervenciones prácticas merece una atención detenida. Sin embargo, no hay garantía de que este esfuerzo sea exitoso, ya que nunca hay garantías en la investigación científica. Sin embargo, este esfuerzo vale la pena si el objetivo es el de construir un mejor planeta para las generaciones presentes y futuras. Estamos convencidos de que un enfoque basado en la gestión del conocimiento puede llevar a soluciones creativas para alcanzar el objetivo de un sistema agrícola (y una sociedad) sostenible.

SOME WORDS OF GRATITUDE

"Get your motor runnin'
Head out on the highway
Lookin' for adventure
and whatever comes our way"
(*Steppenwolf*)

When I started this project, I thought I would make a breakthrough in sustainability science. I thought I would find the "silver bullet". Today, I have to recognize that, so far, there has not been such breakthrough and the conflicts around the world, remain more less the same. I did not create the ultimate silver bullet either. What happened then?. Making operational what seemed difficult to measure gave a lot of strenght to my brain. Aiming at transmitting what I believe can signify a direction to a better world was a pleasure for my heart. Being able to help and laugh was a joy to my soul and to accept I cannot do everything on my own was a challenge to my spirit. All this kept (and keeps) me moving. Miving is a privilege for my body. So, as they mentioned on a movie "moving is living". Now, it is time to thank those who helped me to move or in some cases, even better, to those who decided to move by my side, no matter what.

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If this worked was possible to be printed is because some brilliant minds considered appropriate to be published. I am grateful with my reading committee.

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When I think about the endeavor of working for 4 years to get a PhD degree. I also think about the periods I felt I collapse (as when the Dutch trains do when it snows), other times I felt joy (as when we see the first sunshine after 5 months of cold, wind, rain, snow, and darkness). Nevertheless, isn´t life just like this? Every project I have participated in has been like that, every friend that has followed a carreer (scientific or not) has passed through this. Then, what makes a PhD different? In my case, it was the fact that even though it was a specific project to accomplish, it was not the ultimate project. While pursuing my PhD I also had the opportunity to devote time to (discover) different projects, including no having projects. I have not had such freedom before. Among my discoveries where people. People with whom I had the pleasure and honor to learn, to enjoy life.

Many persons deserve to be mentioned. While writing these last sentences a lot of mixed emotions come to my mind. I hope you accept my sincere apologies If I explicitely do not write your name. The amount of memories and names can be overwhelming at this moment. In exchange, I will share some of the places/moments that I am sure you will identify. Here we go, Zernike Complex (work first of course ;D), Schiphol, Vera, Pintellier, Whiskey Bar, De Kar, Pak Huis, Warhol, Het Feest, Martini House (and the different student houses), Noorderzon, Benzine Bar (honest, how did I get there? :D), Santana, Coffee Company, Summer Schools, Winter Schools, Conferences, En Zo, Het Feest, Plaza Sportiva, Hemmingways, Ni-Hao, Café Kult, Kebab places in town, Pacific, OOG Radio, Kink FM, O'ceallaigh, Het ORKZ, concert halls all over the Netherlands, Drie Uiltjes, Shadrak and Images. Nevertheless, if that is your desire, I will succumb to the vanity of writing something for you.

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My mate of what I denominated…, I guess I cannot write it here but for the time being let's call it "Rock & Roll" (you may know what I mean) is Giulio. My knowledge in most languages is limited to expressions for toasts and some random phrases I learned one way or another. Italian is not the exception but I give it a try: Fratelo, grazie per la tua amicizia. Forza e onore nella nostra vita. Dimmi che ti piace…!!.

Someone that doesn't need presentation. The Beast!. Padrino, tu eres la estrella de la película. NPI como agradecer tu amistad. Gracias por las noches con una botella de mezcal, y dice: "cantando voy por la vida nomás recorriendo el mundo, si quieren que se los diga yo soy un alma sin dueño a mi no me importa nada pa'mi la vida es un sueño..".Gracias c….n, gracias por todo!.

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Jesús Rosales Carreón
Somewhere in the Dutch railways
2012